AD-A160 864 SIMULATION AND EVALUATION OF THE AT&T PROPOSED PATTERN RECOGNITION ALGORI..(U) DELTA INFORMATION SYSTEMS INC HORSHAM PA D BODSON 11 JUN 85 NCS-TIB-85-4 1/1

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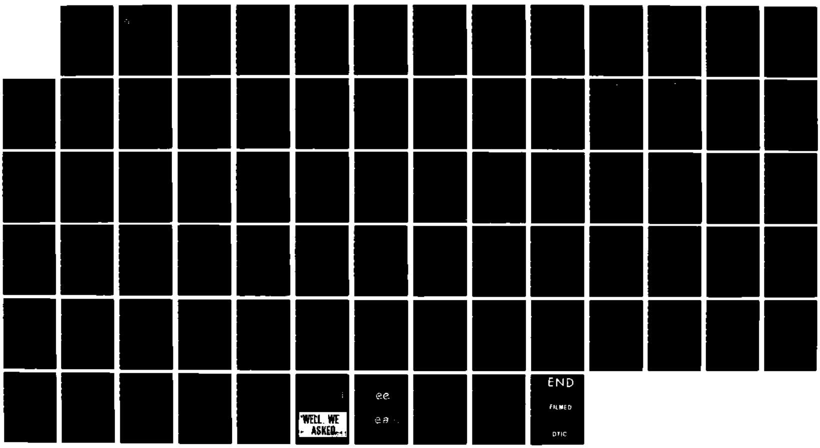

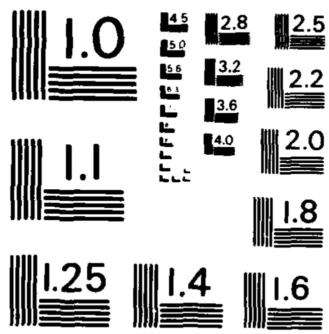

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

(2)

NCS TIB 85-4

NATIONAL COMMUNICATIONS SYSTEM

AD-A160 864

AD-A160 864

TECHNICAL INFORMATION BULLETIN
85-4

SIMULATION AND EVALUATION OF THE AT&T PROPOSED PATTERN RECOGNITION ALGORITHM FOR GROUP 4 FACSIMILE

JUNE 1985

AD-A160 864

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19 ABSTRACT (Continue on reverse if necessary and identify by block number) The CCITT is actively working toward the standardization of Group 4 facsimile. One of the key elements of this CCITT recommendation shall be the compression algorithm for encoding the transmitted facsimile signal. A preliminary standard for this coding technique has been established consisting of an extension of the Group 3 Modified READ Code (MRC). Several investigators have studied a class of more advanced compression techniques which recognize recurring patterns (such as textual characters) and transmit a short ASCII-like code to represent such a symbol. The compression for this type of coding algorithm exceeds that for the basic Group 4 algorithm by a significant degree. Since these compression techniques normally require an error free environment, which is available in Group 4 Facsimile, AT&T has submitted a specific proposal (Appendix B) to the CCITT for the design of such a pattern recognition coding technique. The purpose of this effort was to simulate and evaluate the AT&T proposal.

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SIMULATION AND EVALUATION OF THE AT&T PROPOSED PATTERN RECOGNITION ALGORITHM FOR GROUP 4 FACSIMILE

JUNE 1985

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APPROVED FOR PUBLICATION:

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Office of NCS Technology
and Standards

FOREWORD

Among the responsibilities assigned to the Office of the Manager, National Communications System, is the management of the Federal Telecommunication Standards Program. Under this program, the NCS, with the assistance of the Federal Telecommunication Standards Committee identifies, develops, and coordinates proposed Federal Standards which either contribute to the interoperability of functionally similar Federal telecommunication systems or to the achievement of a compatible and efficient interface between computer and telecommunication systems. In developing and coordinating these standards, a considerable amount of effort is expended in initiating and pursuing joint standards development efforts with appropriate technical committees of the Electronic Industries Association, the American National Standards Institute, the International Organization for Standardization, and the International Telegraph and Telephone Consultative Committee of the International Telecommunication Union. This Technical Information Bulletin presents an overview of an effort which is contributing to the development of compatible Federal, national, and international standards in the area of facsimile standards. It has been prepared to inform interested Federal activities of the progress of these efforts. Any comments, inputs or statements of requirements which could assist in the advancement of this work are welcome and should be addressed to:

Office of the Manager
National Communications System
ATTN: NCS-TS
Washington, DC 20305
(202) 692-2124

SIMULATION AND EVALUATION OF THE AT&T PROPOSED PATTERN RECOGNITION ALGORITHM FOR GROUP 4 FACSIMILE

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Horsham Business Center, Bldg. 3

300 Welsh Road

Horsham PA 19044

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APPENDICES

Appendix A - Program Visual Table of Content (VTOCS)

Appendix B - AT&T Proposal for Pattern Recognition Coding for Group 4 Facsimile

1.0 INTRODUCTION

This document summarizes the work performed by Delta Information Systems, Inc. for the Office of Technology and Standards of the National Communications System, an organization of the U.S. Government, under Task 1 of Contract number DCA100-83-C-0047.

The purpose of the task is to simulate and evaluate the pattern recognition algorithm proposed by AT&T for Group 4 facsimile. The Office of Technology and Standards, headed by National Communications System Assistant Manager Marshall L. Cain, is responsible for the management of the Federal Telecommunications Standards Program, which develops telecommunications standards whose use is mandatory by all federal agencies.

The CCITT is actively working toward the standardization of Group 4 facsimile. One of the key elements of this CCITT recommendation shall be the compression algorithm for encoding the transmitted facsimile signal. A preliminary standard for this coding technique has been established consisting of an extensicn of the Group 3 Modified READ Code (MRC). Several investigators have studied a class of more advanced compression techniques which recognize recurring patterns (such as textual characters) and transmit a short ASCII-like code to represent such a symbol. The compression for this type of coding algorithm exceeds that for the basic Group 4 algorithm by a significant degree. Since these compression techniques normally require an error free environment,

which is available in Group 4 Facsimile, AT&T has submitted a specific proposal (Appendix B) to the CCITT for the design of such a pattern recognition coding technique.

1.1 Algorithm Overview

The Pattern Recognition Algorithm processes the facsimile image by extracting patterns from the image and attempting to recognize them. The input image is examined line by line. When a black pel is found an attempt to isolate the pattern to which it belongs is made. If the pattern can not be isolated within a window (32x32 bits for 200 lines/inch) a piece of the pattern is extracted from the image. Isolated patterns are then compared with already identified patterns which are stored in a library. If a match is found the position of the pattern in the image and its location in the library are coded. If no match is found the pattern is added to the library and the bit image of the pattern and its position are coded. The primary criterion for a no match decision is an error pel with an error weight of four or more (see Appendix B Section 3.3.a). For the purposes of this evaluation all images were processed with a reject threshold of four and also a reject threshold of three. For a complete description of the pattern recognition coding algorithm see Appendix B.

2.0 TASK 1.0 - COMPUTER SOFTWARE

2.1 Overview

In order to evaluate the Group 4 Pattern Recognition Algorithm, two software programs,G4RECENCODE & G4RECDECODE, were written to simulate the facsimile encode and decode functions described in the AT&T proposal to the CCITT dated November, 1984. The software was written in Fortran X3.9-1978 with MIL-STD-1758 Extensions. The G4RECENCODE program processes the input document image creating a coded output file and a library pattern file (See Figure 2.1). The G4RECDECODE program then processes the coded output file recreating from it the document image and a library pattern file (See Figure 2.1). Along with these files, a log or statistics file was generated which contained the following information.

1) Overall Image Statistics

   Total Coded Bits Per Image

   Compression Ratio

   Average Coded Bits Per Image Line

2) Components of the Total Coded Bits Per Image

   Mode Bits

   Horizontal Position Bits

   No More Pattern Bits

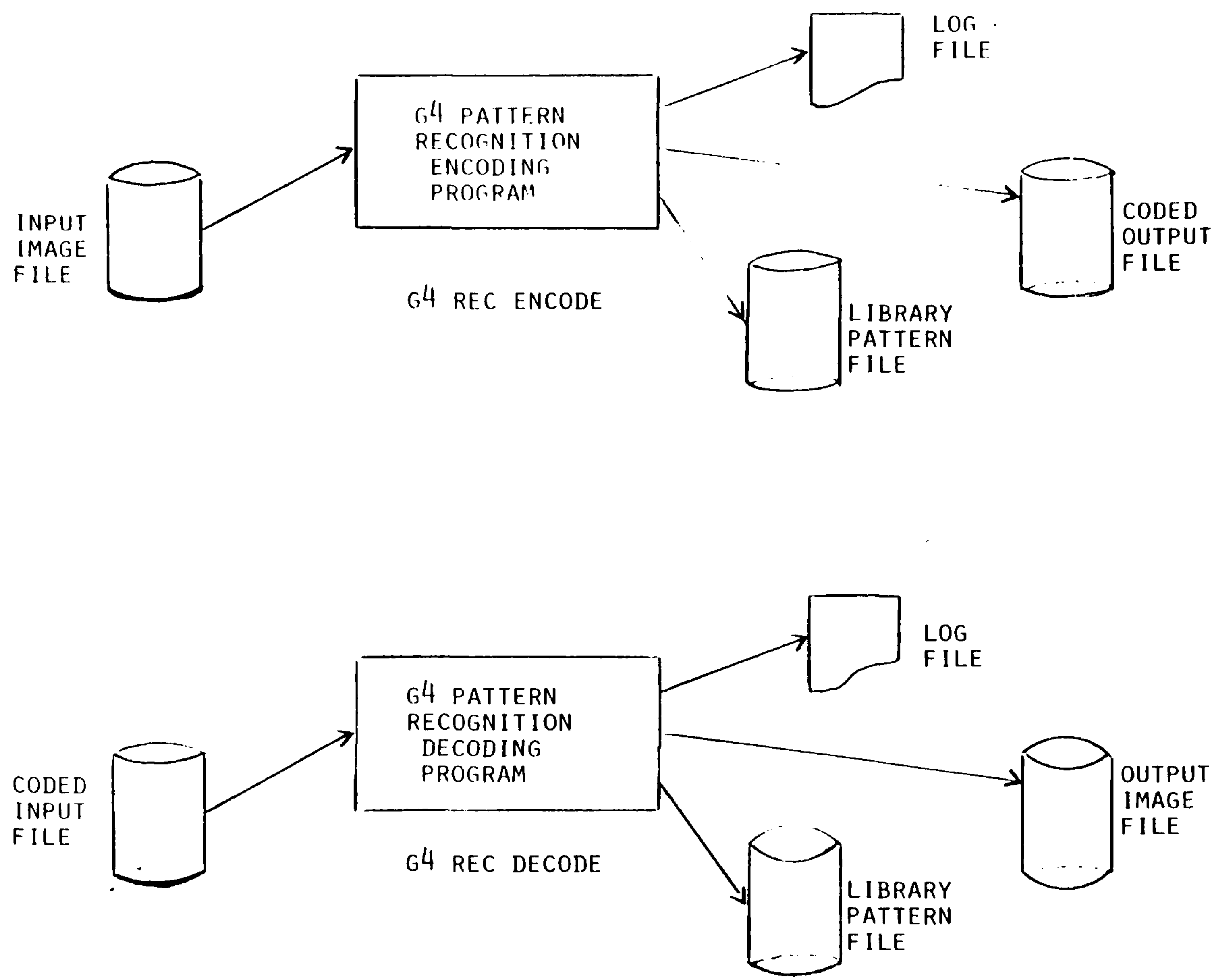
   Vertical Displacement Bits

   Library ID Bits

   Library Pattern Size Bits

   Coded Library Pattern Bits

3) Pattern Recognition Statistics Per Image



G4 PATTERN
RECOGNITION
ENCODING
PROGRAM
INPUT
IMAGE
FILE
LOG
FILE
CODED
OUTPUT
FILE
LIBRARY
PATTERN
FILE
G4 REC ENCODE
G4 PATTERN
RECOGNITION
DECODING
PROGRAM
CODED
INPUT
FILE
LOG
FILE
OUTPUT
IMAGE
FILE
LIBRARY
PATTERN
FILE
G4 REC DECODE

FIGURE 2.1

Number of Patterns

Number of Recognized Pattern

Number of Library Matches Per Incoming Pattern

2.2 Resolution Dependent Program Variations

Since the images to be processed were at four different resolutions, the G4RECENCODE & G4RECDECODE programs were written to accomodate three different pattern window sizes, 32 bits, 48 bits, and 64 bits. It was also necessary to increase the number of horizontal position bits and library pattern size bits by one to accomodate resolutions of 240 and greater. The L-Pattern vertical count was determined by dividing the pattern window size by three thereby giving counts of 10, 16, and 21 for 32, 48 and 64 bit windows respectively. Noise bit removal was also dependent on resolution and was determined as follows:

1) If the window is 32 bits, any isolated symbol whose height and width was two or less and whose bit population was two or less was removed.
2) If the window is 48 bits any isolated symbol whose height and width was three or less and whose bit population was four or less was removed.
3) If the window is 64 bits any isolated symbol whose height and width was four or less and whose bit population was eight or less was removed.

The feature differences used in the library screening procedure were held constant across all resolution for the initial 24 computer runs and then doubled for three additional runs of the 400 bit images for the three CCITT documents selected.

3.0 TASK 2.0 - COMPUTER SIMULATION

Twenty-four computer simulation runs were done which consisted on the following:

CCITT Test Pages 1, 5, 7

Resolutions (Lines/Inch) - 200, 240, 300, 400

Rejection thresholds - 3, 4

In addition three computer simulation runs were done with the feature differences increased as stated in Section 2.2. These consisted of:

CCITT Test Pages 1, 5, 7

Resolution - 400

Rejection Threshold - 4

Tables 3.1 through 3.3 shows the results of the first 24 computer runs. Table 3.1 lists the overall image compression statistics. Table 3.2 lists all the components of the coded output bits. Table 3.3 lists the information generated by the pattern recognition algorithm pertaining to the number of patterns per image, number of recognized pattern per image and number of library matches per incoming pattern. Tables 3.4 through 3.6 show the corresponding results for the three additional computer runs.

As can been seen in Table 3.1 compression ratios approximated doubled as the resolution went from 200 to 400 lines per inch. There was also a decrease in compression ratio when the reject threshold was decreased to three. This decrease ranged from 4.4% to 14.8% on CCITT Document #1, 7.6% to 16.3% on CCITT Document #5 and 16.3% to 19.5% on CCITT Document #7.

IMAGE COMPRESSION STATISTICS TABLE 3.1

CCITT IMAGE	RESOLUTION	REJECTION THRESHOLD	TOTAL INPUT BITS	CODED OUTPUT BITS	COMPRESSION RATIO	AVG CODED BITS/IMAGE LINE
	200	4	4036608	45756	88.22	19.59
	240	4	5736448	52695	108.86	18.81
#1	300	4	8960000	62878	142.50	17.97
ENGLISH	400	4	16146432	87893	183.71	18.81
LETTER	200	3	4036608	47853	84.35	20.49
	240	3	5736448	56081	102.29	20.02
	300	3	8960000	69675	128.60	19.91
	400	3	16146432	103173	156.50	22.08
	200	4	4036608	74287	54.38	31.80
	240	4	5736448	86245	66.51	30.79
#5	300	4	8960000	104964	85.36	29.99
FRENCH	400	4	16146432	144636	111.64	30.95
JOUR-	200	3	4036608	80314	50.26	34.38
NAL	240	3	5736448	94429	60.75	33.71
	300	3	8960000	118587	75.56	33.88
	400	3	16146432	172749	93.47	36.97
	200	4	4036608	212162	19.02	90.82
	240	4	5736448	250532	22.90	89.44
#7	300	4	8960000	287922	31.12	82.26
KANJI	400	4	16146432	392732	41.11	84.06
	200	3	4036608	253376	15.93	108.47
	240	3	5736448	300721	19.08	107.36
	300	3	8960000	349833	25.61	99.95
	400	3	16146432	487744	33.10	104.40

CODED OUTPUT BITS TABLE 3.2

CCITT IMAGE	RESOLUTION	REJECTION THRESHOLD	MODE BITS	HORIZ POS BITS	NO MORE PATERN BITS	VERTICAL DISPL BITS	LIBRARY ID BITS	LIB PATTERN SIZE BITS	CODED LIB PATTERN BIT	TOTAL OUTPUT BITS
	200	4	2336	12287	912	1195	5132	1038	22856	45756
	240	4	2801	12948	993	1167	5152	1127	28507	52695
	300	4	3500	13404	990	1220	5068	1365	37331	62878
#1	400	4	4672	13632	1398	1197	5777	1680	59537	87893
ENGLISH	200	3	2336	12287	912	1183	5108	1152	24875	47853
LETTER	240	3	2801	12948	993	1123	5146	1323	31747	56081
	300	3	3500	13404	990	1140	5177	1631	43833	69675
	400	3	4672	13632	1398	1109	5905	2142	74315	103173
	200	4	2336	27148	2163	2812	11966	1458	26404	74287
	240	4	2801	28512	2283	2708	12017	1925	35999	86245
	300	4	3500	29808	2853	2722	13281	2324	50476	104964
#5	400	4	4672	29988	2991	2666	13708	3108	87503	144636
FRENCH	200	3	2336	27148	2163	2700	12290	1806	31871	80314
JOURNAL	240	3	2801	28512	2283	2607	12167	2366	43693	94429
	300	3	3500	29808	2853	2586	13698	2996	63146	118587
	400	3	4672	29988	2991	2489	14277	4123	114209	172749
	200	4	2336	37411	4359	3812	21672	3582	138990	212162
	240	4	2801	45300	5001	3969	24357	4627	164477	250532
	300	4	3500	43776	5310	3933	24593	4536	202274	287922
#7	400	4	4672	46452	6678	4130	27205	5467	298128	392732
KANJI	200	3	2336	37411	4359	3387	21847	4650	179386	253376
	240	3	2801	45300	5001	3701	24158	5971	213789	300721
	300	3	3500	43776	5310	3687	24507	5803	263250	349833
	400	3	4672	46452	6678	3728	27148	7154	391912	487744

PATTERN RECOGNITION STATISTICS TABLE 3.3

CCITT IMAGE	RESOLUTION	REJECTION THRESHOLD	# OF PATTERNS/ IMAGE	# OF RECOGNIZE PATTERNS	# OF LIBRARY MATCHES/PAT
	200	4	1117	944	3.01
	240	4	1079	918	2.48
	300	4	1117	922	2.06
#1	400	4	1136	896	1.81
ENGLISH	200	3	1117	925	3.47
LETTER	240	3	1079	890	2.96
	300	3	1117	884	2.67
	400	3	1136	830	2.78
	200	4	2468	2225	2.56
	240	4	2376	2101	2.21
	300	4	2484	2152	2.13
#5	400	4	2499	2055	2.17
FRENCH	200	3	2468	2167	3.11
JOURNAL	240	3	2376	2038	2.87
	300	3	2484	2056	2.95
	400	3	2499	1910	3.47
	200	4	3401	2804	5.62
	240	4	3775	3114	3.43
	300	4	3648	3000	2.45
#7	400	4	3871	3090	1.82
KANJI	200	3	3401	2626	7.45
	240	3	3775	2922	4.46
	300	3	3648	2819	3.11
	400	3	3871	2849	2.23

IMAGE COMPRESSION STATISTICS TABLE 3.4

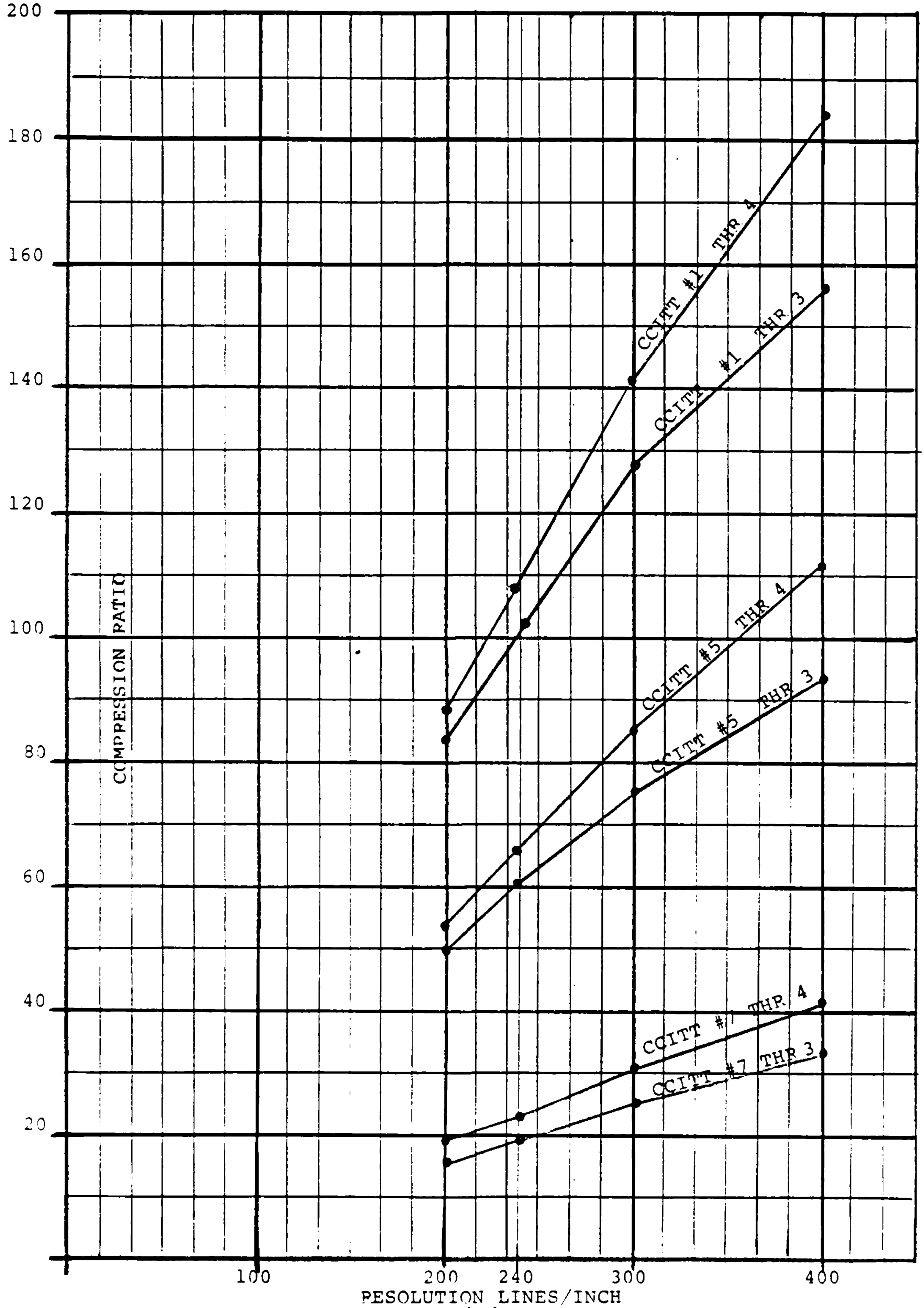
CCITT IMAGE	RESOLUTION	REJECTION THRESHOLD	TOTAL INPUT BITS	CODED OUTPUT BITS	COMPRESSION RATIO	AVG. CODED BITS/ IMAGE LINE
#1 ENGLIGH LETTER	400	4	16146432	87846	183.80	18.80
#5 FRENCH JOURNAL	400	4	16146432	144030	113.10	30.83
#7 KANJI	400	4	16146432	387990	41.62	83.05

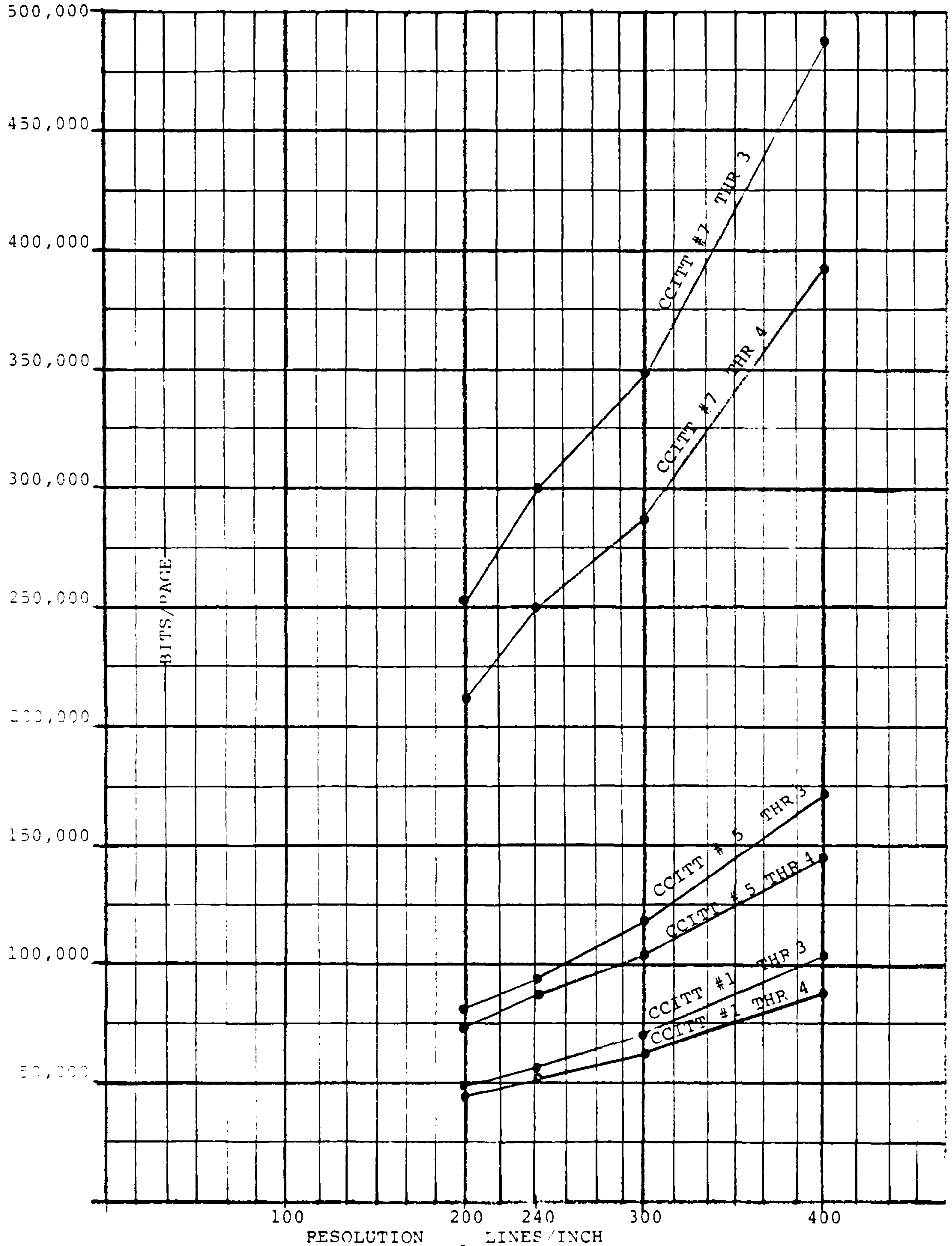
CODED OUTPUT BITS TABLE 3.5

CCITT IMAGE	RESOLUTION	REJECTION THRESHOLD	MODE BITS	HORIZ POS BITS	NO MORE PATTERN BITS	VERTICAL DISPLAY BITS	LIBRARY ID BITS	LIB PATTERN SIZE BITS	CODED LIB PATTERN BITS	TOTAL OUTPUT BITS
#1 ENGLISH LETTER	400	4	4672	13632	1398	1217	5710	1680	59537	87846
#5 FRENCH JOURNAL	400	4	4672	29988	2991	2676	13495	3094	87114	144030
#7 KANJI	400	4	4672	46452	6678	4170	26865	5411	293742	387990

PATTERN RECOGNITION STATISTICS TABLE 3.6

CCITT IMAGE	RESOLUTION	REJECTION THRESHOLD	# OF PATTERNS/ IMAGE	# OF RECOGNIZED PATTERNS	# OF LIBRARY MATCHES/PAT
#1 ENGLISH LETTER	400	4	1136	896	4.18
#5 FRENCH JOURNAL	400	4	2499	2057	4.48
#7 KANJI	400	4	3871	3098	4.90


200
180
160
140
120
100
80
60
40
20
COMPRESSION RATIO
CCITT #1 THR 4
CCITT #1 THR 3
CCITT #5 THR 4
CCITT #5 THR 3
CCITT #7 THR 4
CCITT #7 THR 3
100
200
240
300
400
RESOLUTION LINES/INCH



500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
BITS/PAGE
CCITT #7 THR 3
CCITT #7 THR 4
CCITT # 5 THR 3
CCITT # 5 THR 4
CCITT #1 THR 3
CCITT #1 THR 4
100
200
240
300
400
PESOLUTION LINES/INCH

From Table 3.2 it can be seen that the coded library pattern bit are the major part of the coded output bits, making up anywhere from 35% to 50% of the coded output bits.

Table 3.3 lists pattern recognition information from each of the 24 computer runs. It should be noted that on all eight runs of the CCITT Document #7 the library pattern file limit of 512 patterns was exceeded. If the library pattern file were increased in size in all probability the compression ratios would improve for this document.

Figures 3.1 and 3.2 are graphs of the data in Table 3.1 for coded bits/page and the compression ratio respectively.

Reviewing the results of the additional three runs of the 400 lines per inch image file with the loosened feature requirements, there was only a very slight increase in compression ratios. Comparing the corresponding lines in tables 3.3 and 3.6 it is interesting to note that although the number of compares per incoming pattern at least doubled, the number of recognized patterns changed very little if at all.

4.0 TASK 3.0 - IMAGE EVALUATION

After processing the coded image files by the G4RECDECODE program, the resulting output image file for each image was printed. Each output image was visually compared against the original input image. There were on the lowest resolution images, 200 lines to the inch, and a reject threshold of four, some areas where one symbol was replaced by a similar symbol. All of these substitutions occurred on punctuation, lower case alpha characters, or small size upper case characters. See Figures 4.1 - 4.9. Figures 4.10 and 4.11 are Bit Image Printouts of part of the small characters at the botton of the English Document showing a lower case e/s substitution. On all three CCITT Documents these substitutions were reduced when the same image was processed at a reject threshold of three. On CCITT Document #1 (English Letter) and CCITT Document #7 (Kanji) there were no apparent substitutions on resolutions 240, 300 and 400 line per inch. On CCITT Document #5 there were some small symbol substitutions in the drawings at 240 lines per inch at a reject threshold of four but almost all of these disappeared at a reject threshold of three. (See Figures 4.12 and 4.13.)

Another area of difference was found on the CCITT Document #5 (French Journal) where vertical and horizontal line segments would appear ragged and varied in stroke thickness. This is present in the output image of all resolutions but is much less pronounced at the higher resolutions. (See Figures 4.14 and 4.15.)

THE SLEREXE COMPANY LIMITED

SAPORS LANE - BOOLE - DORSET - BH 25 8 ER

TELEPHONE BOOLE (945 13) 51617 - TELEX 123456

Our Ref. 350/PJC/EAC 18th January, 1972.

Dr. P.N. Cundall,
Mining Surveys Ltd.,
Holroyd Road,
Reading,
Berks.

Dear Pete,

Permit me to introduce you to the facility of facsimile transmission.

In facsimile a photocell is caused to perform a raster scan over the subject copy. The variations of print density on the document cause the photocell to generate an analogous electrical video signal. This signal is used to modulate a carrier, which is transmitted to a remote destination over a radio or cable communications link.

At the remote terminal, demodulation reconstructs the video signal, which is used to modulate the density of print produced by a printing device. This device is scanning in a raster scan synchronised with that at the transmitting terminal. As a result, a facsimile copy of the subject document is produced.

Probably you have uses for this facility in your organisation.

Yours sincerely,

Phil.

P.J. CROSS
Group Leader - Facsimile Research

Registered in England: No. 2038
Registered Office: 60 Vicars Lane, Ilford. Essex.

ORIGINAL INPUT IMAGE

CCITT DOCUMENT # 1 - ENGLISH LETTER - 200 LINES PER INCH

FIGURE 4.1

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Phil.

P.J. CROSS
Group Leader - Facsimile Research

Registered in England: No. 2008
Registered Office: 60 Vicars Lane, Ilford, Essex.

OUTPUT IMAGE

CCITT DOCUMENT # 1 - ENGLISH LETTER - 200 LINES PER INCH

REJECT THRESHOLD - 4

FIGURE 4.2

THE SLEREXE COMPANY LIMITED

SAPORS LANE - BOOLE - DORSET - BH 25 8 ER

TELEPHONE BOOLE (945 13) 51617 - TELEX 123456

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Probably you have uses for this facility in your organisation.

Yours sincerely,

Phil.

P.J. CROSS
Group Leader - Facsimile Research

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OUTPUT IMAGE

CCITT DOCUMENT #1 - ENGLISH LETTER - 200 LINES PER INCH

REJECT THRESHOLD - 3

FIGURE 4.3

Cela est d'autant plus valable que $T\Delta f$ est plus grand. A cet égard la figure 2 représente la vraie courbe donnant $|\phi(f)|$, en fonction de f pour les valeurs numériques indiquées page precédente.

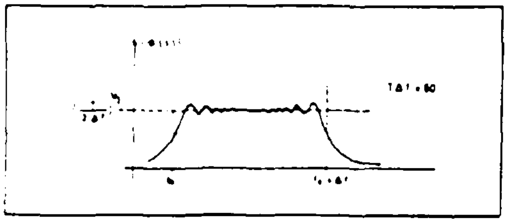

FIG. 2

Dans ce cas, le filtre adapté pourra être constitué, conformément à la figure 3, par la cascade :

— d'un filtre passe-bande de transfert unité pour $f_0 \leq f \leq f_0 + \Delta f$ et de transfert quasi nul pour $f < f_0$ et $f > f_0 + \Delta f$, filtre ne modifiant pas la phase des composants le traversant ;

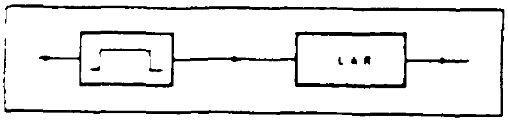

FIG. 3

— filtre suivi d'une ligne à retard (LAR) dispersive ayant un temps de propagation de groupe T_R décroissant linéairement avec la fréquence f suivant l'expression :

$$T_R = T_0 + (f_0 - f)\,\frac{T}{\Delta f} \quad (\text{avec } T_0 > T)$$

(voir fig. 4).

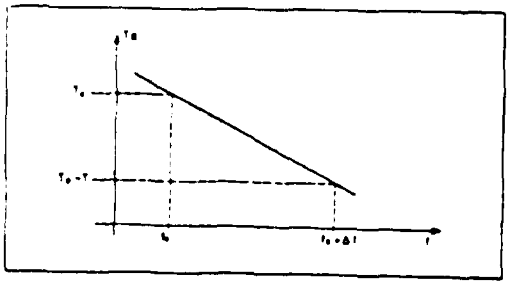

FIG. 4

telle ligne à retard est donnée par :

$$\varphi = -2\pi \int_0^f T_R \, df$$

$$\varphi = -2\pi \left[T_0 + \frac{f_0 T}{\Delta f} \right] f + \pi \frac{T}{\Delta f} f^2$$

Et cette phase est bien l'opposé de $/\phi(f)$,

à un déphasage constant près (sans importance) et à un retard T_0 près (inévitable).

Un signal utile $S(t)$ traversant un tel filtre adapté donne à la sortie (à un retard T_0 près et à un déphasage près de la porteuse) un signal dont la transformée de Fourier est réelle, constante entre f_0 et $f_0 + \Delta f$, et nulle de part et d'autre de f_0 et de $f_0 + \Delta f$, c'est-à-dire un signal de fréquence porteuse $f_0 + \Delta f/2$ et dont l'enveloppe a la forme indiquée à la figure 5, où l'on a représenté simultanément le signal $S(t)$ et le signal $S_1(t)$ correspondant obtenu à la sortie du filtre adapté. On comprend le nom de récepteur à compression d'impulsion donné à ce genre de filtre adapté : la « largeur » (à 3 dB) du signal comprimé étant égale à $1/\Delta f$, le rapport de compression est de $\dfrac{T}{1/\Delta f} = T\Delta f$

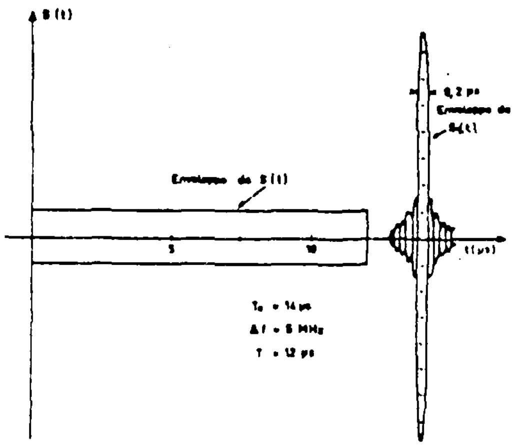

FIG. 5

On saisit physiquement le phénomène de compression en réalisant que lorsque le signal $S(t)$ entre dans la ligne à retard (LAR) la fréquence qui entre la première à l'instant 0 est la fréquence basse f_0, qui met un temps T_0 pour traverser. La fréquence f entre à l'instant $t = (f - f_0)\dfrac{T}{\Delta f}$ et elle met un temps $T_0 - (f - f_0)\dfrac{T}{\Delta f}$ pour traverser, ce qui la fait ressortir à l'instant T_0 également. Ainsi donc, le signal $S(t)$

ORIGINAL INPUT IMAGE

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FIGURE 4.4

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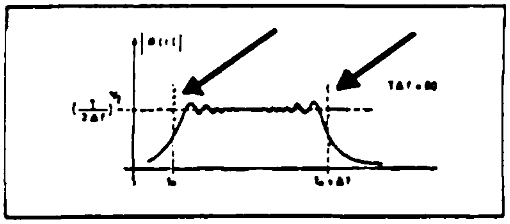

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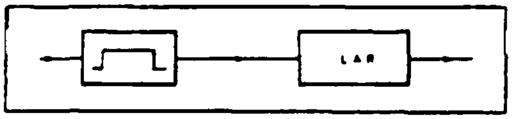

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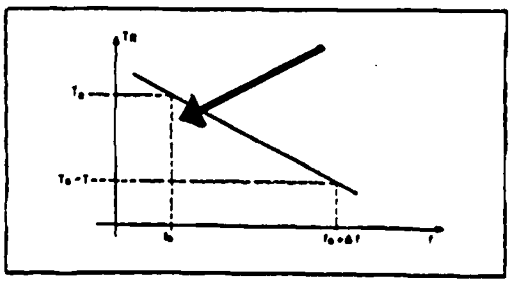

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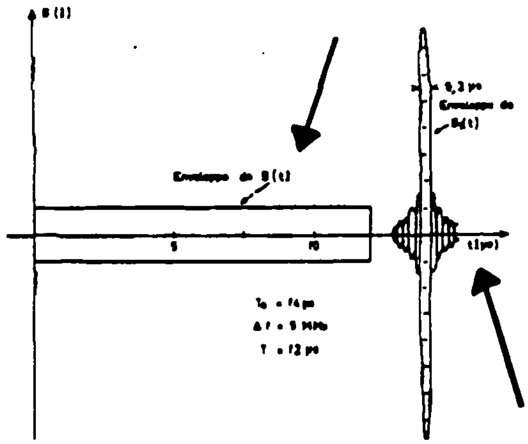

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On saisit physiquement le phénomène de compression en réalisant que lorsque le signal $S(t)$ entre dans la ligne à retard (LAR) la fréquence qui entre la première à l'instant 0 est la fréquence basse f_0, qui met un temps T_0 pour traverser. La fréquence f entre à l'instant $t = (f-f_0)\dfrac{T}{\Delta f}$ et elle met un temps $T_0-(f-f_0)\dfrac{T}{\Delta f}$ pour traverser, ce qui la fait ressortir à l'instant T_0 également. Ainsi donc, le signal $S(t)$

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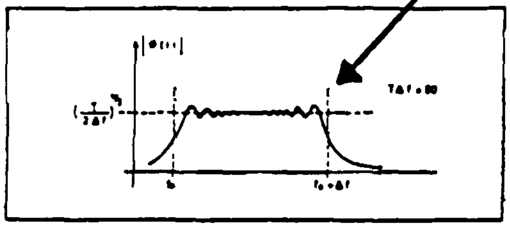

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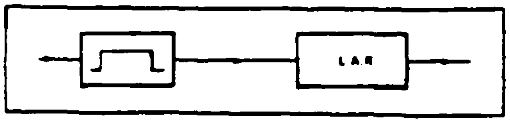

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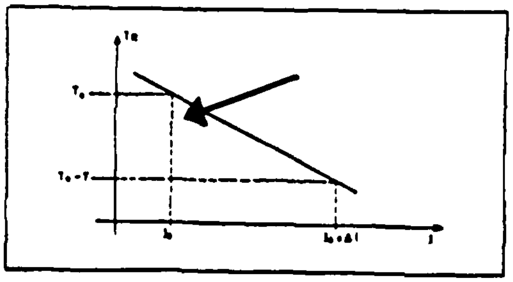

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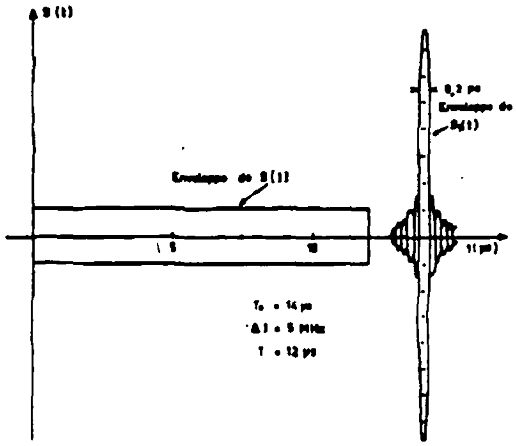

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CCITTの概要

沿革

CCITTは、国際電気通信連合（ITU）の四つの常設機関（事務総局、国際周波数登録委員会、CCIR、CCITT）の一つとして、ITUの中でも、世界の国際通信上の諸問題を真先に取上げ、その解決方法を見出して行く重要な機関である。日本名は、国際電信電話諮問委員会と称する。

CCITTの前身は、CCIF（国際電話諮問委員会）とCCIT（国際電信諮問委員会）である。CCIFは、1924年にヨーロッパに「国際長距離電話通信諮問委員会」が設置され、これが1925年のパリ電信電話会議のとき、正式に、「国際電話諮問委員会」として万国電信連合の公式機関となったものである。CCITは、同じく1925年の会議のとき、CCIFと併立するものとして設置された。

そして、CCIFは、1956年の12月に第18回総会が開催されたのち、CCITは、同年同月に第8回総会が開催されたのち、併合されて現在のCCITTとなった。このCCITTは、CCIFとCCITが解散した直後、第1回総会を開催し、第2回総会は、1960年にニューデリーで、第3回総会は、1964年、ジュネーブで、第4回総会は、1968年、アルゼンチンで開催された。

CCIFとCCITが合併したのは、有線電気通信の分野、とくに伝送路について電信回線と電話回線とを技術的に分ける意味がなくなってきたこと、各国とも大体において、電信部門と電話部門は同一組織内にあること、CCIFの事務局とCCITの事務局の合併による能率増進等がおもな理由であった。

CCITTは、上述のように、ヨーロッパ内の国ぐにによって、ヨーロッパ内の電信・電話の技術・運用・料金の基準を定め、あるいは統一をはかってきたので、現在でも、その影響を受け、会合参加国は、ヨーロッパの国が多く、ヨーロッパで生起する問題の研究が多い。たとえば、1960年のCCITT勧告の中で、技術上配慮する距離は約2,500㎞であったが、これはヨーロッパ内領域を想定したものである。

しかしながら、1956年9月に敷設された大西洋横断電話ケーブルは、大陸間電話通信の自動化および半自動化への技術的可能性を与え、CCITTがこの問題を取り上げるに及び、CCITTの性格は漸次、汎世界的色彩を実質的に帯びるに至った。この汎世界的性格は第2次世界大戦後目ざましくなったアジア・アフリカ植民地の独立に伴ってITUの構成員の中にこれらの国が加わり、ITUの中に新しい意見が導入されたことにも起因して、技術面、政治面の双方から導入されてきた。CCITTの汎世界化は、1960年の第2回総会がニューデリーで開催されたことにもあらわれている。この総会までは、CCIT、CCIFのいずれにしろ、アメリカやアジアで総会が開催されたことがなく、CCITT委員長も、ニューデリー総会の準備文書で、この点には注目すべきであるとのべている。

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上記第187号と第188号にいわれる「意見」とは、フランス語の Avis から訳したもので、英語では、「勧告(Recommendation)」となっている。CCITTの表明する意見は、国際法的には強制力をもたないものであって、この点が、条約、電信規則、電話規則等各国を拘束する力をもっているものと異なる。もっとも意見とは称しても、技術的分野では、電信規則のごとき、各国政府が承認してその内容を実施する強制規則をもたないので、実際にある機器の仕様を定める場合には、多くの国の意見が統一されたこの「意見」に従わなければ、円滑な国際通信を行なうことができない場合が多い。この意見（または勧告）は、国際通信を行なう場合各国が直面する問題について、具体的意見を表明するもので、たとえば、大陸間ケーブルで大陸間通話を半自動化しようとする場合、その信号方式や取り扱う通話の種類および料金は、どのようにするかを研究して意見を表明する。したがって、CCITTの活動は、つねに時代の最先端を行くもので、CCITTの活動方向は、そのまま世界の国際通信の活動方向であるともいえる。

この意見は、また、電信規則以下のその他の規則のごとく、数年以上の間隔をもって開催される主管庁会議というような大会議の決定をまたなくても表明することができ、また、その改正も容易であるので、現在のように進歩の早い国際通信界では、関係国の意見を統一した国際的見解としては非常に便利である。

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CCITT DOCUMENT # 7 - KANJI - 200 LINES PER INCH

FIGURE 4.7

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この意見は、また、電信規則以下のその他の規則のごとく、数年以上の間隔をもって開催される主管庁会議というような大会議の決定をまたなくても表明することができ、また、その改正も容易であるので、現在のように進歩の早い国際通信界では、関係国の意見を統一した国際的見解としては非常に便利である。

OUTPUT IMAGE

CCITT DOCUMENT # 7 - KANJI - 200 LINES PER INCH

REJECT THRESHOLD - 4

FIGURE 4.8

CCITTの概要

沿革

CCITTは、国際電気通信連合（ITU）の四つの常設機関（事務総局、国際周波数登録委員会、CCIR、CCITT）の一つとして、ITUの中でも、世界の国際通信上の諸問題を真先に取上げ、その解決方法を見出して行く重要な機関である。日本名は、国際電信電話諮問委員会と称する。

CCITTの前身は、CCIF（国際電話諮問委員会）とCCIT（国際電信諮問委員会）である。CCIFは、1924年にヨーロッパに「国際長距離電話通信諮問委員会」が設置され、これが1925年のパリ電信電話会議のとき、正式に、「国際電話諮問委員会」として万国電信連合の公式機関となったものである。CCITは、同じく1925年の会議のとき、CCIFと併立するものとして設置された。

そして、CCIFは、1956年の12月に第18回総会が開催されたのち、CCITは、同年同月に第8回総会が開催されたのち、併合されて現在のCCITTとなった。このCCITTは、CCIFとCCITが解散した直後、第1回総会を開催し、第2回総会は、1960年にニューデリーで、第3回総会は、1964年、ジュネーブで、第4回総会は、1968年、アルゼンチンで開催された。

CCIFとCCITが合併したのは、有線電気通信の分野、とくに伝送路について電信回線と電話回線とを技術的に分ける意味がなくなってきたこと、各国とも大体において、電信部門と電話部門は同一組織内にあること、CCIFの事務局とCCITの事務局の合併による能率増進等がおもな理由であった。

CCITTは、上述のように、ヨーロッパ内の国ぐにによって、ヨーロッパ内の電信・電話の技術・運用・料金の基準を定め、あるいは統一をはかってきたので、現在でも、その影響を受け、会合参加国は、ヨーロッパの国が多く、ヨーロッパで生起する問題の研究が多い。たとえば、1960年のCCITT勧告の中で、技術上配慮する距離は約2,500kmであったが、これはヨーロッパ内領域を想定したものである。

しかしながら、1956年9月に敷設された大西洋横断電話ケーブルは、大陸間電話通信の自動化および半自動化への技術的可能性を与え、CCITTがこの問題を取り上げるに及び、CCITTの性格は漸次、汎世界的色彩を実質的に帯びるに至った。この汎世界的性格は第2次世界大戦後目ざましくなったアジア、アフリカ植民地の独立に伴ってITUの構成員の中にこれらの国が加わり、ITUの中に新しい意見が導入されたことにも起因して、技術面、政治面の双方から導入されてきた。CCITTの汎世界化は、1960年の第2回総会がニューデリーで開催されたことにもあらわれている。この総会までは、CCIT、CCIFのいずれにしろ、アメリカやアジアで総会が開催されたことがなく、CCITT委員長も、ニューデリー総会の準備文書で、この点には注目すべきであるとのべている。

任務

ITUは、全権委員会議、主管庁会議を始めとして、七つの機関をもち、それぞれの機関の権限と任務は国際電気通信条約に明記されている。そこで条約を参照してみるならば、CCITTの任務は、つぎのとおりとなっている。

「国際電信電話諮問委員会(CCITT)は、電信および電話に関する技術、運用および料金の問題について研究し、および意見を表明することを任務とする。」（1965年モントルー条約第187号）

「各国際諮問委員会は、その任務の遂行に当たって、新しい国または発展の途上にある国における地域的および国際的分野にわたる電気通信の創設、発達および改善に直接関連のある問題について研究し、および意見を作成するように妥当な注意を払わなければならない。」（同第188号）

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OUTPUT IMAGE

CCITT DOCUMENT #7 - KANJI - 200 LINES PER INCH

FIGURE 4.9 REJECT THROSHOLD - 3

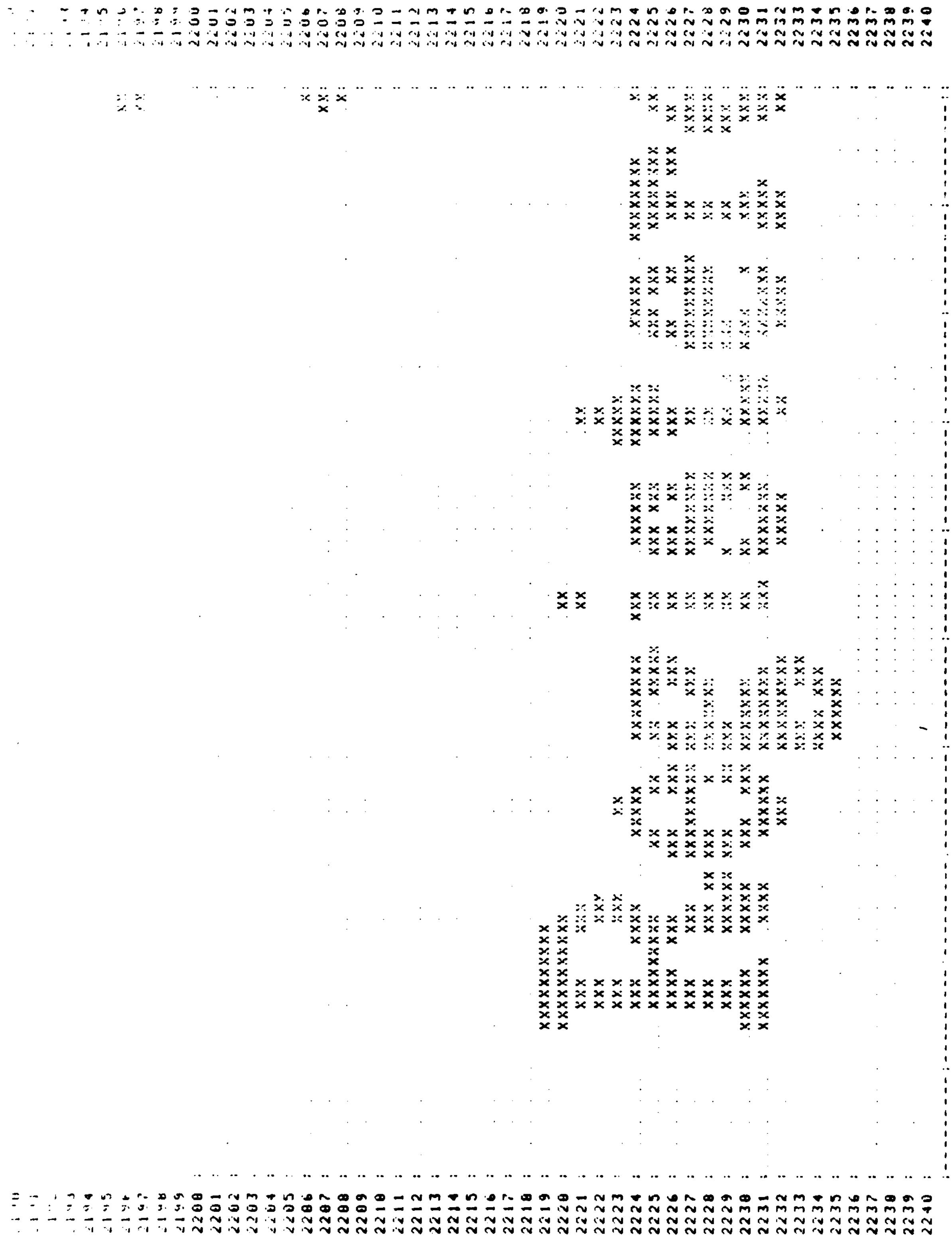


FIGURE 4.10

ORIGINAL INPUT IMAGE

CCITT DOCUMENT #1 - 200 LINES PER INCH

BIT IMAGE PRINTOUT

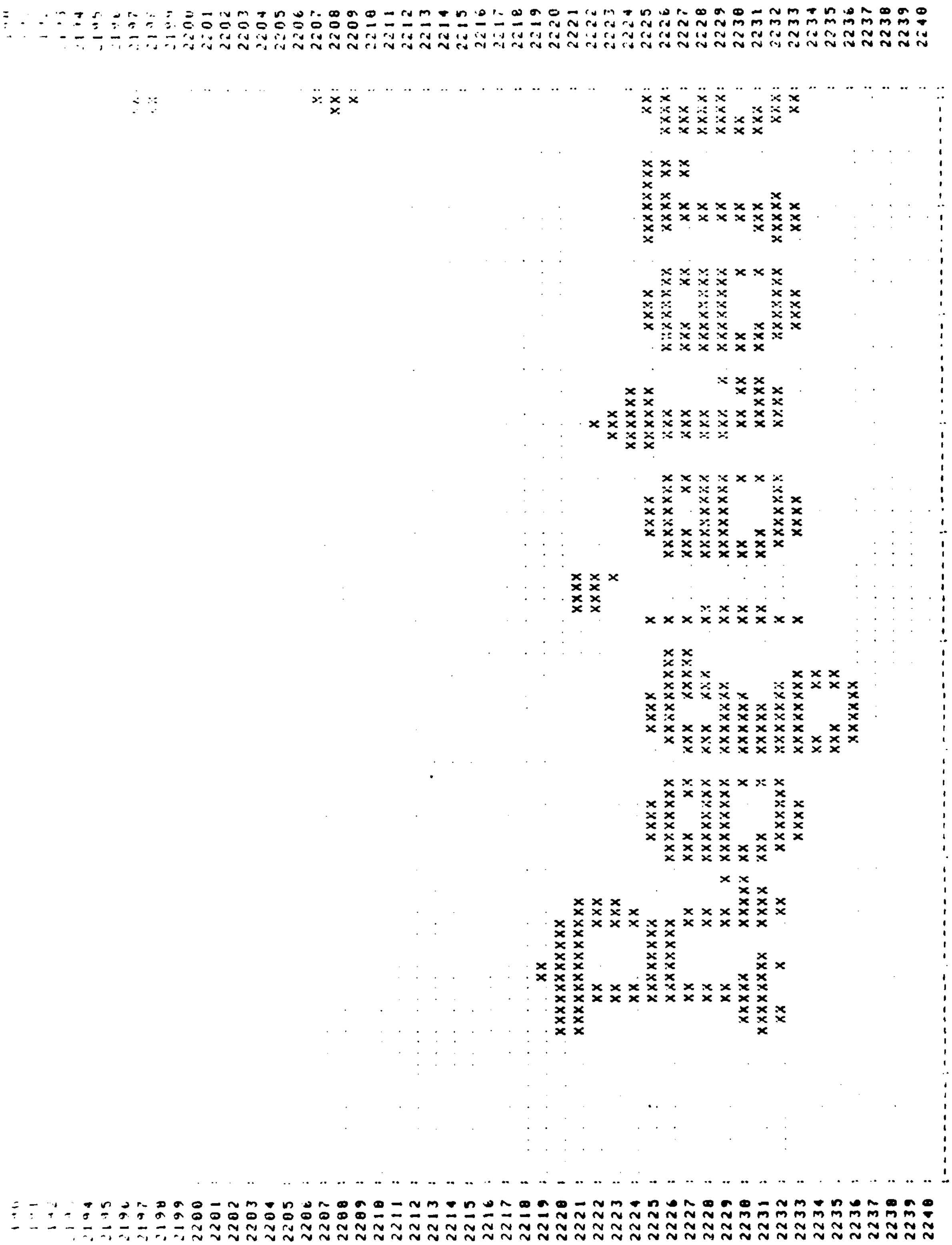


FIGURE 4.11

OUTPUT IMAGE

CCITT DOCUMENT #1 - 200 LINES PER INCH
BIT IMAGE OUTPUT
REJECT THRESHOLD - 4

Cela est d'autant plus valable que $T\Delta f$ est plus grand. A cet égard la figure 2 représente la vraie courbe donnant $|\phi(f)|$ en fonction de f pour les valeurs numériques indiquées page précédente.

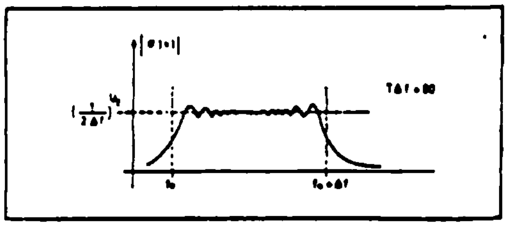


Fig. 2

Dans ce cas, le filtre adapté pourra être constitué, conformément à la figure 3, par la cascade :

— d'un filtre passe-bande de transfert unité pour $f_0 \leq f \leq f_0+\Delta f$ et de transfert quasi nul pour $f < f_0$ et $f > f_0+\Delta f$, filtre ne modifiant pas la phase des composants le traversant ;

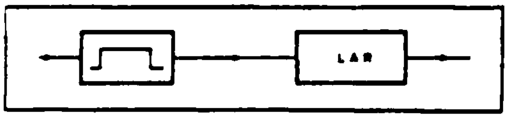


Fig. 3

— filtre suivi d'une ligne à retard (LAR) dispersive ayant un temps de propagation de groupe T_R décroissant linéairement avec la fréquence f suivant l'expression :

$$T_R = T_0+(f_0-f)\frac{T}{\Delta f} \quad (\text{avec } T_0 > T)$$

(voir fig. 4).

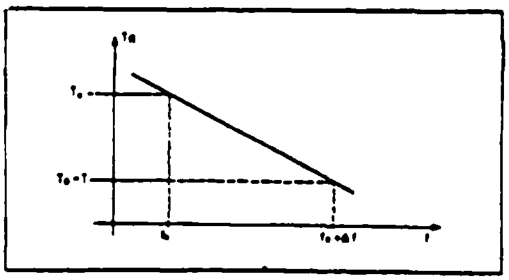


Fig. 4

telle ligne à retard est donnée par :

$$\varphi = -2\pi \int_0^f T_R \, df$$

$$\varphi = -2\pi \left[T_0+\frac{f_0 T}{\Delta f}\right] f + \pi \frac{T}{\Delta f} f^2$$

Et cette phase est bien l'opposé de $/\phi(f)$,

à un déphasage constant près (sans importance) et à un retard T_0 près (inévitable).

Un signal utile $S(t)$ traversant un tel filtre adapté donne à la sortie (à un retard T_0 près et à un déphasage près de la porteuse) un signal dont la transformée de Fourier est réelle, constante entre f_0 et $f_0+\Delta f$, et nulle de part et d'autre de f_0 et de $f_0+\Delta f$, c'est-à-dire un signal de fréquence porteuse $f_0+\Delta f/2$ et dont l'enveloppe a la forme indiquée à la figure 5, où l'on a représenté simultanément le signal $S(t)$ et le signal $S_1(t)$ correspondant obtenu à la sortie du filtre adapté. On comprend le nom de récepteur à compression d'impulsion donné à ce genre de filtre adapté : la « largeur » (à 3 dB) du signal comprimé étant égale à $1/\Delta f$, le rapport de compression est de $\dfrac{T}{1/\Delta f} = T\Delta f$

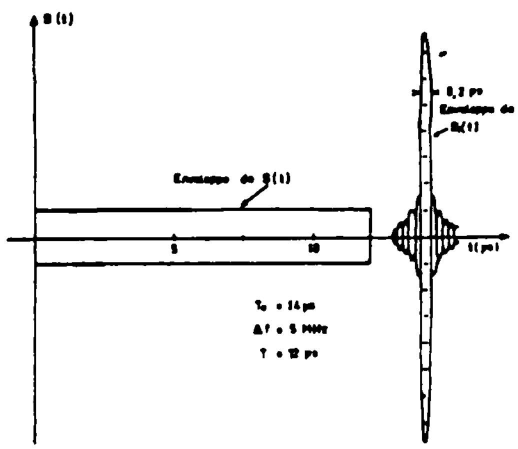
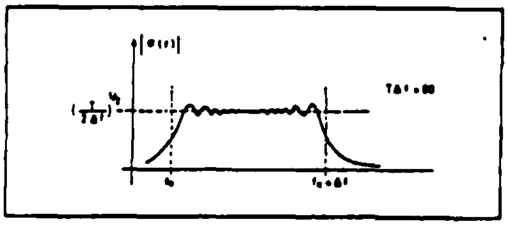


Fig. 5

On saisit physiquement le phénomène de compression en réalisant que lorsque le signal $S(t)$ entre dans la ligne à retard (LAR) la fréquence qui entre la première à l'instant 0 est la fréquence basse f_0, qui met un temps T_0 pour traverser. La fréquence f entre à l'instant $t = (f-f_0)\dfrac{T}{\Delta f}$ et elle met un temps $T_0-(f-f_0)\dfrac{T}{\Delta f}$ pour traverser, ce qui la fait ressortir à l'instant T_0 également. Ainsi donc, le signal $S(t)$

4-13

Cela est d'autant plus valable que $T\Delta f$ est plus grand. A cet égard la figure 2 représente la vraie courbe donnant $|\phi(f)|$ en fonction de f pour les valeurs numériques indiquées page précédente.



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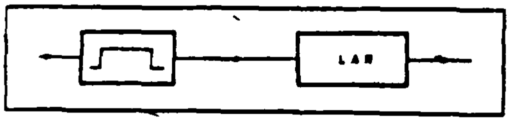

FIG. 3

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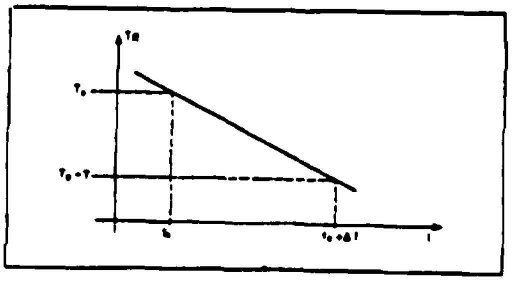

FIG. 4

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$$\varphi = -2\pi\left[T_0+\frac{f_0T}{\Delta f}\right]f+\pi\frac{T}{\Delta f}f^2$$

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à un déphasage constant près (sans importance) et à un retard T_0 près (inévitable).

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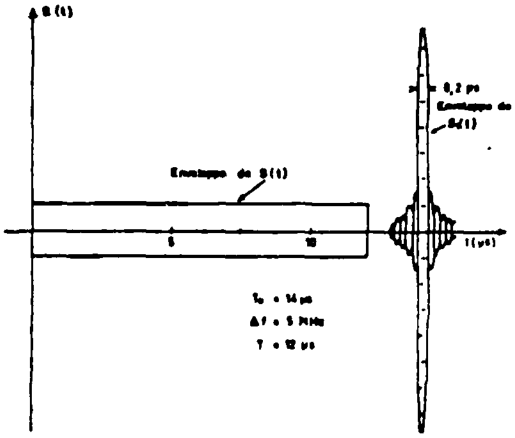

FIG. 5

On saisit physiquement le phénomène de compression en réalisant que lorsque le signal $S(t)$ entre dans la ligne à retard (LAR) la fréquence qui entre la première à l'instant 0 est la fréquence basse f_0, qui met un temps T_0 pour traverser. La fréquence f entre à l'instant $t = (f-f_0)\frac{T}{\Delta f}$ et elle met un temps $T_0-(f-f_0)\frac{T}{\Delta f}$ pour traverser, ce qui la fait ressortir à l'instant T_0 également. Ainsi donc, le signal $S(t)$

OUTPUT IMAGE

CCITT DOCUMENT #5 - FRENCH JOURNAL - 240 LINES PER INCH
REJECT THRESHOLD - 3

FIGURE 4.13

Cela est d'autant plus valable que $T\Delta f$ est plus grand. A cet égard la figure 2 représente la vraie courbe donnant $\phi(f)$ en fonction de f pour les valeurs numériques indiquees page précedente.

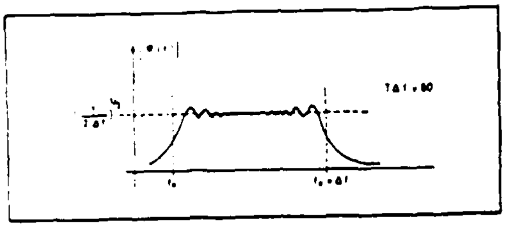

Fig. 2

Dans ce cas, le filtre adapté pourra être constitué, conformément à la figure 3, par la cascade :

— d'un filtre passe-bande de transfert unité pour $f_0 \leqslant f \leqslant f_0+\Delta f$ et de transfert quasi nul pour $f < f_0$ et $f > f_0+\Delta f$, filtre ne modifiant pas la phase des composants le traversant ;

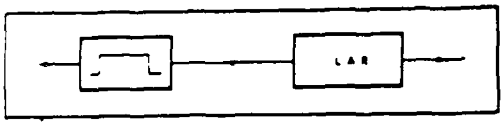

Fig. 3

— filtre suivi d'une ligne à retard (LAR) dispersive ayant un temps de propagation de groupe T_R décroissant linéairement avec la fréquence f suivant l'expression

$$T_R = T_0 + (f_0 - f)\,\frac{T}{\Delta f} \quad (\text{avec } T_0 > T)$$

(voir fig. 4)

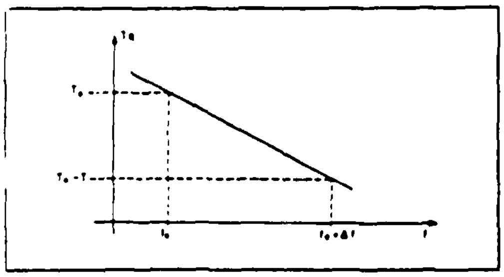

Fig. 4

telle ligne à retard est donnée par :

$$\varphi = -2\pi \int_0^f T_R \, df$$

$$\varphi = -2\pi \left[T_0 + \frac{f_0 T}{\Delta f} \right] f + \pi \frac{T}{\Delta f} f^2$$

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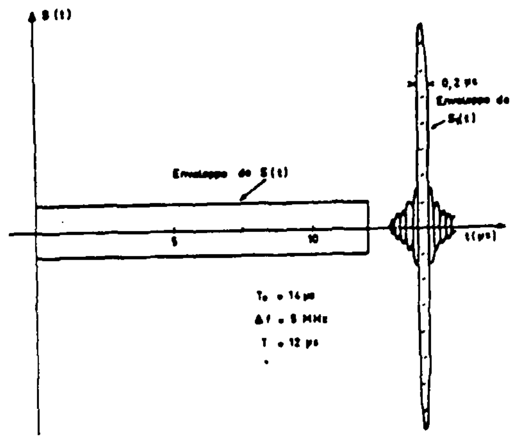

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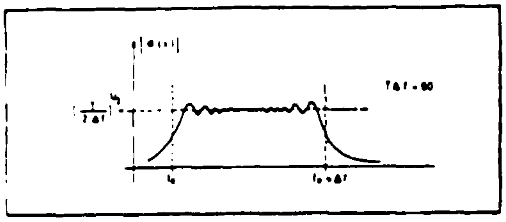

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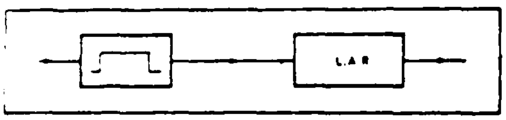

Fig. 3

— filtre suivi d'une ligne à retard (LAR) dispersive ayant un temps de propagation de groupe T_R *décroissant linéairement avec la fréquence f suivant* l'expression :

$$T_R = T_0 + (f_0 - f)\,\frac{T}{\Delta f} \quad (\text{avec } T_0 > T)$$

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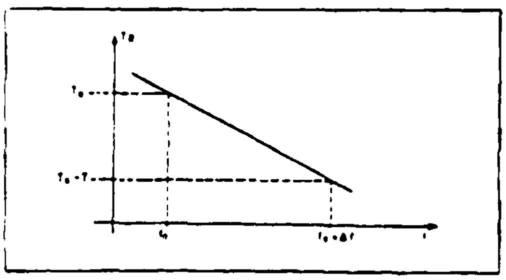

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telle ligne à retard est donnée par :

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Et cette phase est bien l'opposé de $/\phi(f)$,

à un déphasage constant près (sans importance) et à un retard T_0 près (inévitable).

Un signal utile $S(t)$ traversant un tel filtre adapté donne à la sortie (*à un retard* T_0 *près* et à un déphasage près de la porteuse) un signal dont la transformée de Fourier est réelle, constante entre f_0 et $f_0 + \Delta f$, et nulle de part et d'autre de f_0 et de $f_0 + \Delta f$, c'est-à-dire un signal de fréquence porteuse $f_0 + \Delta f/2$ et dont l'enveloppe a la forme indiquée à la figure 5, où l'on a représenté simultanément le signal $S(t)$ et le signal $S_1(t)$ correspondant obtenu à la sortie du filtre adapté. On comprend le nom de récepteur à compression d'impulsion donné à ce genre de filtre adapté : la « largeur » (à 3 dB) du signal comprimé étant égale à $1/\Delta f$, le rapport de compression est de $\dfrac{T}{1/\Delta f} = T\Delta f$

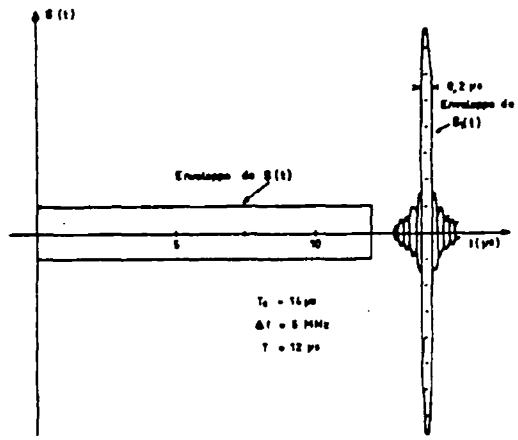


Fig. 5

On saisit physiquement le phénomène de compression en réalisant que lorsque le signal $S(t)$ entre dans la ligne à retard (LAR) la fréquence qui entre la première à l'instant 0 est la fréquence basse f_0, qui met un temps T_0 pour traverser. La fréquence f entre à l'instant $t = (f - f_0)\,\dfrac{T}{\Delta f}$ et elle met un temps $T_0 - (f - f_0)\,\dfrac{T}{\Delta f}$ pour traverser, ce qui la fait ressortir à l'instant T_0 également. Ainsi donc, le signal $S(t)$

OUTPUT IMAGE

CCITT DOCUMENT #5 - FRENCH JOURNAL - 300 LINES PER INCH

REJECT THRESHOLD - 3

FIGURE 4.15

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Table 5.1 lists the compression ratios of Modified READ Code II algorithm as stated in the final report on "Measurement of Compression of the Modified READ Code II" by Delta Information Systems, Inc. for the National Communication System under Contract No DCA100-80-C-0042. Also listed are the Compression ratio for the pattern recognition algorithm at reject thresholds of three and four. As can be seen, the pattern recognition algorithm shows a significant increase in compression ratios over the MRCII with the greatest increases at the higher resolutions at a reject threshold of four. As stated in Section 4, the pattern recognition algorithm did allow some small symbol substitutions at resolutions of 200 and 240 but these had little if any effect on the content of the document.

5.2 Recommendations

The compression ratios achieved by the pattern recognition algorithm are dependent on the symbol matching rate and the Modified READ II coding of the library pattern. Because of this the performance of the recognition algorithm should be evaluated on Document images of varying print quality; additionally the current evaluation of the pattern recognition algorithm did not attempt to improve the algorithm's read rate performance or thruput performance. It is suggested that the algorithm be evaluated with the following variations:

1) Increased library size for the CCITT Document #7 since the 512 library pattern limit caused the retransmission of many symbols.
2) Prestored libraries.

CCITT IMAGE	RESOLUTION	COMP RATIO MRC II	COMP RATIO RECOG THR4	% DIFF	COMP RATIO RECOG THR3	% DIFF
	200	30.57	88.22	188.6	84.35	175.9
#1	240	36.54	108.86	197.9	102.29	179.9
ENGLISH	300	45.44	142.50	213.6	128.60	183.0
LETTER	400	59.57	183.71	208.4	156.50	162.7
	200	17.61	54.38	208.8	50.26	185.4
#5	240	21.00	66.51	216.7	60.75	189.3
FRENCH	300	25.91	85.36	229.4	75.56	191.6
JOURNAL	400	34.55	111.64	223.1	93.47	170.5
	200	7.59	19.02	150.6	15.93	109.8
#7	240	9.12	22.90	151.1	19.08	109.2
KANJI	300	11.43	31.12	172.3	25.61	124.1
	400	15.50	41.11	165.2	33.10	113.5

COMPARISON OF MRC II AND PATTERN RECOGNITION

COMPRESSION RATIOS

TABLE 5.1

3) Reject threshold variations as a function of resolution.

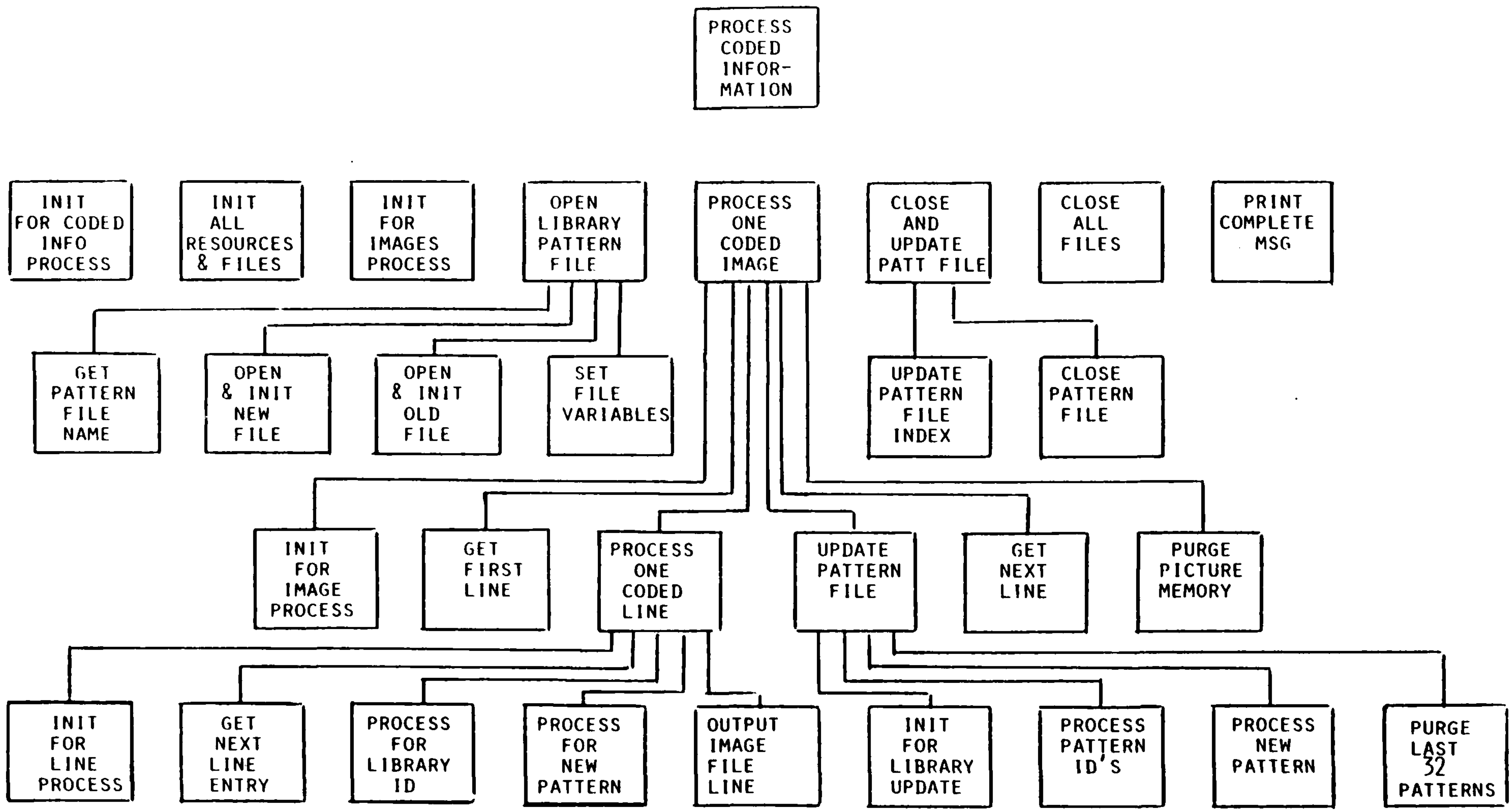
4) Variable library screening feature difference counts should be evaluated for different resolutions.

5) The pattern matching and error PEL evaluation are very time consuming. Currently the incoming pattern and library pattern are compared and evaluated at nine pcsitions. Some evaluation of an early exit should the current compare give a sufficiently low error count (good match) or sufficiently high error count (no match) should be done.

APPENDIX A

PROGRAM VISUAL TABLE OF CONTENTS

(VTOCS)



G4RECDECODE VISUAL TABLE OF CONTENTS

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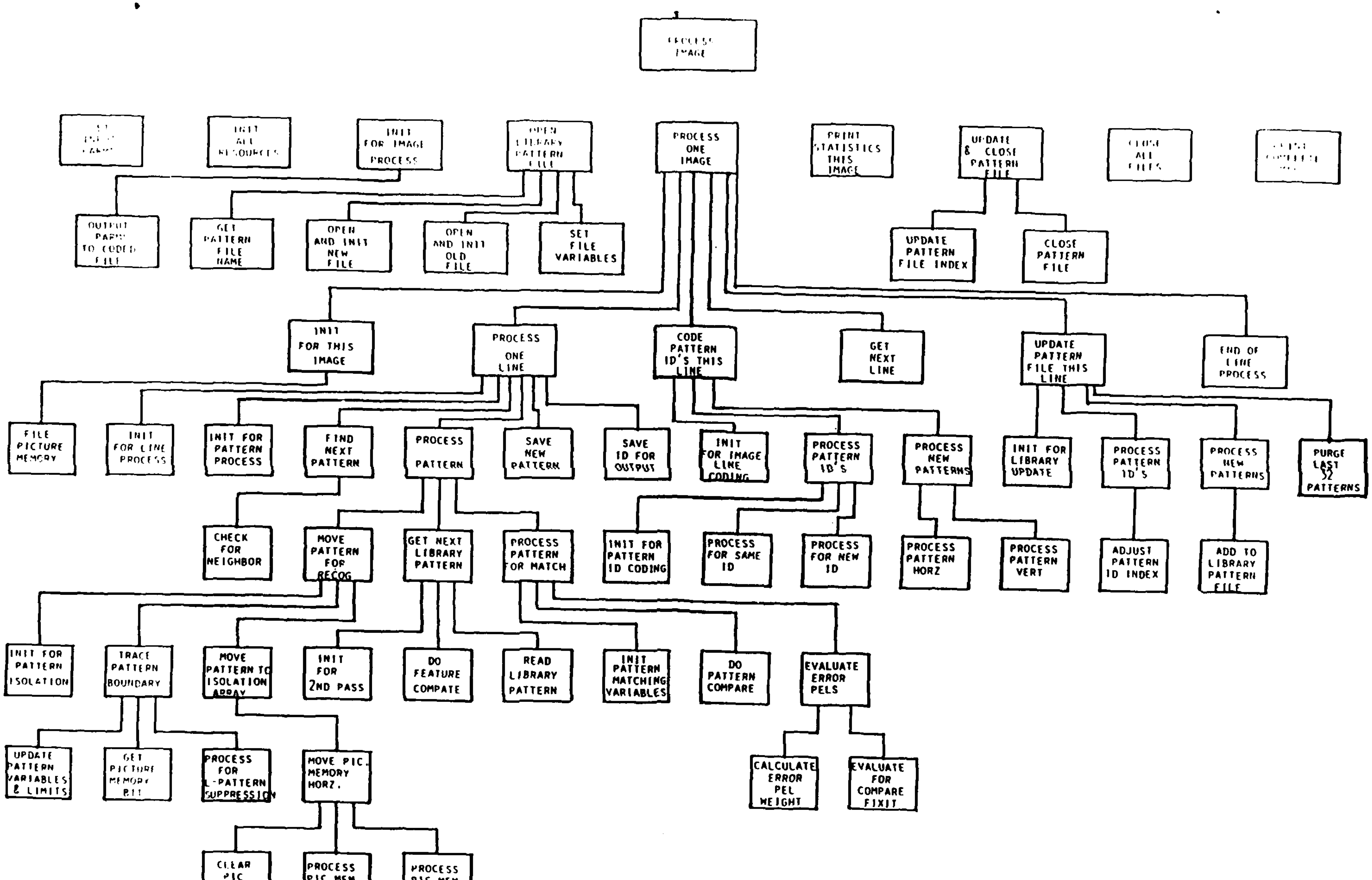


G4RECENCODE VISUAL TABLE OF CONTENTS

APPENDIX A

Geneva May, 1983
Questions: 7/VIII,25/VIII,12/VIII

SOURCE: AT&T

TITLE: PATTERN RECOGNITION CODING FOR GROUP 4 FACSIMILE

1. INTRODUCTION

Facsimile engineers have long sought better coding schemes in order to improve transmission efficiency. Since 1979 when the Modified Read algorithm was standardized, new algorithms have been discovered that are able to achieve an improvement in compression efficiency by as much as a factor of five. These new algorithms typically require an error free environment which is for the first time available in Group 4 facsimile. Therefore, it is timely to consider adopting one of these new algorithms as an optional coding mode for Group 4 facsimile.

AT&T has been studying facsimile coding extensively and has developed a new algorithm that may represent an advance over previously published algorithms. The algorithm is described in this paper. AT&T urges that this new algorithm be adopted as an optional coding scheme for Group 4 facsimile.

2. PROPOSAL

Before describing the new algorithm, it is useful to consider via an example the improvement in facsimile compression if patterns in an image are recognized. Consider CCITT test document 4 which is essentially all text. The Modified Read algorithm can achieve a compression ratio of about 7.4. Next consider a case where document 4 is directly captured as key strokes and is encoded via an ordinary 8 bit character code. The second procedure would yield an equivalent compression ratio of 105.5. In examining the differences between the two approaches, the major factor is that in the character coding case, a human has recognized the characters in the message. This allows the characters to be encoded in a very efficient manner. Traditional facsimile coding exploits only microscopic properties of images. In the case of the Modified Read Algorithm, the coder only looks at immediately neighboring pels. It should be obvious that a gain in coding efficiency is possible if a coder can combine a set of microscopic properties in order to recognize and code the actual macroscopic structure of the image.

The new AT&T coding scheme exploits macroscopic properties of images. Patterns such as characters or line segments which appear in a facsimile image several times are described and transmitted only once. The next time the same pattern is found, a special codeword will indicate that it is identical to a previously transmitted pattern.

A facsimile image is examined line by line. When a black pel is located, a "pattern isolator" surrounds connected pels in order to extract the entire pattern which the pel is a member of. The pattern is decomposed into MxM sub-blocks called symbols. In many cases, a symbol will be an isolated pattern that entirely fits within the MxM block. The incoming symbol is matched with already identified symbols which are stored in a library. If a match is detected, information about the position of the symbol in the image and its location in the library is coded. If no match is found, the incoming symbol is added to the symbol library which is assumed to be empty at the beginning of the coding and is gradually built up. In this case, an accurate description of the symbol and its position in the image is coded.

A block diagram of the coding algorithm is presented in Figure 1. The coding algorithm is described in detail in Appendix 1.

The proposal described in detail in Appendix 1 can be divided into two parts. The coding part, including the library management, contains the rules allowing the communication between coder and decoder. This part must be standardized. The isolation and matching part are presented here only to demonstrate the feasibility of the system. Each manufacturer can, within the limits imposed by the coding standardization, develop its own proprietary isolation and matching algorithms.

3. RESULTS

Appendix 2 compares the new AT&T algorithm with the Modified Read algorithm. The coding efficiency averaged over the eight CCITT documents is increased by nearly a factor of 2 compared to the Modified Read algorithm. The increase is very high for images that have high character content. For example, the coding efficiency of document 4 can be improved by nearly a factor of 5. An increase in coding efficiency by a factor of about 2 is obtained for images which have a mixture of graphics and text (document 5), signature and text (document 1) and Chinese characters (document 7). For documents which contain hand drawn text and hand drawn graphics, such as document 2 and 8, a slight decrease in coding efficiency is observed.

The new coding algorithm is approximate since the decoded image is not identical to the original. The distortions are very small as can be observed by looking at Figures 2 through 9 which show the eight CCITT documents after coding and subsequent decoding. There are options which allow increasing the fidelity of transmission by tightening the matching. However, an increase in image fidelity generally means that the coding efficiency will be slightly decreased.

Appendix 3 describes how the coding technique can be extended to different document sizes and resolutions. Appendix 3 also discusses those cases where a priori knowledge exists about the type of symbols in a document. This knowledge allows the use of a prestored symbol library. This situation would occur in at least two important cases.

- The case where a multipage document is being coded. The symbol library would be generated on the first page using the coding algorithm described in Appendix 1. The next page would be coded using this symbol library as a starting point. Effectively the coder would view the document as a single page thousands of lines long.

- The case where the type font is known allowing the use of a prestored library.

Experiments with CCITT document 4 have shown that the compression ratio can be increased from 35.4 to 53.7 if the document is coded once to generate a library, and then coded a second time with that library as a starting point.

4. PATENT STATUS

Use of the proposed AT&T coding scheme may require a patent license obtainable from the AT&T Intellectual Property Matters Organization, Greensboro, North Carolina, USA. It is the policy of AT&T to enter into licensing agreements on reasonable terms for the patents that it holds.

5. CONCLUSION

AT&T urges that the study of new optional Group 4 coding schemes be undertaken. It feels, furthermore, that the coding scheme described in this paper would be an excellent choice for adoption as a new CCITT coding standard.

APPENDIX 1: CODING DESCRIPTION

1. SYSTEM DESCRIPTION

Figure 1 shows in block diagram form the AT&T pattern matching coding algorithm. The algorithm has four basic components which are described briefly below. Each subcomponent is described in detail in subsequent sections.

- *Pattern Identification Block* - Image data is fed sequentially left to right, line by line into this block. The pattern identification block scans through the raw image data and determines for each black pel if the pattern it is contained in is either a symbol or a nonsymbol. A symbol is defined as a set of black pels completely surrounded by white pels such that the symbol can be completely contained within a MxM region. A nonsymbol results when the pattern will not fit within the MxM region. Therefore a nonsymbol is a fraction of a black region. All patterns can be decomposed into symbols and nonsymbols. Symbol extraction is nonambiguous since it can only be done one way. Non symbol decomposition can be done in many ways. The AT&T pattern matching algorithm defines only one of these procedures for decomposition. After, extraction, all symbols and non symbols are processed in the same way and hence no further distinction is made between the two.

  The position in the image of each symbol is recorded and the symbol is extracted from the image and stored for subsequent processing. Because all patterns can be decomposed into symbols or non symbols the pattern identifier leaves no residue. Each symbol is passed through a feature extractor that subjects it to a sequence of metrics. The metric description or feature set of the symbol is used for subsequent symbol identification.

- *Library Management Block* - A symbol library stores the symbols that are detected in the course of coding. Initially the library is empty. New symbols and their features are added to the library by an update and management unit. This unit stores symbols rank ordered by the frequency of their occurrence. Infrequently used symbols are deleted from the library as needed to make room for new symbols.

- *Symbol Matching Block* - Only library symbols which have a feature set close to the newly identified symbol are fed to the symbol matching block. The candidate library symbols are template matched against the new symbol. If a correct match is detected, the symbol matching block outputs the library identification of the symbol as well as the position of the symbol in the image. If no match is detected, the symbol matching block outputs a description of the symbol as well as its location. The new symbol will be added to the library by

the symbol library block.

- *Coder Block* - The coder receives either a library identification or a pel by pel description of each new incoming symbol. It also receives information about where the symbol is located within the image. The coder stores all symbols until the end of each scan line. The symbols are sorted by order of occurrence so that the updated library will be closely matched statistically to the symbols in the scan line. Finally for each symbol the pel map or library identification is coded and the coded bits are output for subsequent transmission or storage.

The coder described in this appendix assumes that the width of the image is less than 1792 pels. This condition typically occurs for an A4 document scanned at 200 pels per inch. However, 1792 is not a fundamental restriction. Appendix 3 shows how the coding algorithm can be extended to images of arbitrary size and resolution. Coder overhead is reduced by choosing the smallest possible value for the maximum page width.

A 32x32 pattern window was chosen for use with 200 ppi images because it can enclose most textual symbols. A larger pattern window could be used but it would increase coder complexity. Appendix 3 discusses the use of a larger pattern window, particularly for higher resolution images.

Experience has shown that a 512 entry library is efficient for use with a 32x32 pattern window. Fewer entries could be used but this would require constant retransmission of symbols. A larger library would involve increased overhead.

The window size and maximum page width should be established between the coder and the decoder via protocol.

The first and last rows and columns of the image are assumed to be white. This allows simplified processing of patterns at the edge of the image. It also avoids the use of fictitious pels outside the physical image area. There will be no noticeable reduction in image quality if these pels are set to white.

2. THE PATTERN IDENTIFICATION BLOCK

2.1 Location and Isolation of Symbols

A pattern is defined as a set of connected black pels. A pel in a pattern must connect to at least one of its eight neighbors. The maximum symbol size recognized by the coder is 32x32 pels. Any connected set of black pels within the 32x32 block will be isolated as a symbol. Upon identification, the symbol will be extracted from the image and erased from the image.

Isolated symbols containing only 1 or 2 black pels are simply erased. Any pattern bigger than the 32x32 window will be decomposed into several symbols, using the following partition

rule:

a. the starting pel which is found by sequentially processing the image line by line left to right is always included.

b. All the connected black pels on the right side or under the starting pel are included as long as they are contained in the 32x32 pel window whose upper left pel is the starting pel.

c. As many connected black pels as possible within the 32x32 pel window size are added to the left of the starting pel without loosing the pels stored by procedures a and b above.

d. The identified symbol is extracted and erased from the picture. The next symbol is isolated using rules a), b) and c) until the entire pattern is removed from the image.

This isolation scheme is modified to improve performance by the elimination of some L shaped patterns that appear when isolating a big black region. If beginning with the starting or second pel the isolated pattern has a vertical edge of 10 or more pels, and then a horizontal edge to the right, the lower side of the window is raised so that the horizontal edge will be just excluded.

The position of each isolated symbol is recorded. The location of the symbol is taken to be the upper left pel in the window.

2.2 Feature Extractor

The feature extractor classifies each new symbol so that it can be quickly compared to symbols stored in the library. Features are determined by measuring a new symbol against a set of metrics. The following four features are used:

1. length of symbol (feature 1)

2. height of symbol (feature 2)

3. number of horizontal white runs included in the symbol (feature 3)

4. number of vertical white runs included in the symbol (feature 4)

1) and 2) are self-explanatory. 3) and 4) are the number of white runs followed and preceded by black pels.

3. MATCHING

The matching is divided into three parts: 1)Screening which makes a selection of the library symbols and directs only matching candidates to the template matcher. 2)Template matching which creates a new binary picture called an error picture containing black pels or "1" in the locations where the two template matched

symbols are dissimilar. 3)Matching decision process, which uses the error pictures and other information to decide whether a correct match has occurred.

3.1 Screening

The purpose of the screen is to expedite the matching process. The screen only directs to the template matcher library symbols which have a chance of matching the incoming (unknown) symbol. The screen decides the order in which they are to be sent to the matcher. The most likely candidate for a match is sent first. The probability of a match of symbols depends not only on the similarity of their features, but also on the probability of occurrence of the library symbols. For example, an incoming symbol having the same feature distance to a O and a Q is much more likely to match the O than the Q since O is much more frequent than Q. The probability of occurrence of a symbol is taken into account by sorting the library symbols according to the number of times they have matched. The sorting procedure is described in section 4.3. The feature distance is taken into account by allowing for each feature only a fixed margin between the two symbols.

A two-pass screen has been found to be very efficient. In the first pass, a very tight screen is applied. A second much looser screen is applied only in the few cases where no match occurred.

Let F_i' be the feature value of the incoming symbol for feature i and let F_i' be the same for a library symbol. The tight screen is defined by:

$$|F_1-F_1'|\leq 1 \quad \text{and}$$

$$|F_2-F_2'|\leq 1 \quad \text{and}$$

$$|F_3-F_3'|\leq 5 \quad \text{and}$$

$$|F_4-F_4'|\leq 5$$

The loose screen is used only if the new symbol cannot match any of those library symbols which were identified as possible matches by the tight screening process. The loose screen is defined by:

$$|F_1-F_1'|\leq 3 \quad \text{and}$$

$$|F_2-F_2'|\leq 3 \quad \text{and}$$

$$|F_3-F_3'|\leq 11 \quad \text{and}$$

$$|F_4-F_4'|\leq 11$$

If no match is found even after loose screening, the coder concludes that no match is possible. The symbol is subsequently added to the symbol library.

3.2 Template Matching

The template matcher creates a new picture called an error picture which contains "1" in the locations where the new symbol differs from a symbol stored in the library. It is obtained simply by performing a pel by pel exclusive OR between the two symbols. Figure 10 is an example of where two symbols which represents the same character are matched. Figure 11 shows the matching of two different symbols. As seen from Figure 10, many elements can be in error even if two of the same symbols are matched.

A total of nine template matches are made between two symbols. One of them is obtained when the upper left pel of the two blocks containing the symbols are superimposed while the eight others are obtained by moving one of the symbols horizontally or vertically by one pel or both vertically and horizontally by one pel in all the possible directions.

3.3 Matching Decision

The decision about a match is made by looking at the neighborhood of each error pel in the error picture. The decision is based on a local rejection rule. At each error pel, a rejection test is made. An "error weight" is defined as the number of adjacent neighbors an error pel has. The error weight of a pel can vary from 0 to 8 depending on the neighboring error pels. A match is rejected if:

a. an error pel has an error weight of 4 or more, or

b. an error pel has an error weight of 2 or more and

   1. at least two of its neighboring error pels are not connected and

   2. one of the two pels from the symbols used to obtain the error pel has a corresponding "pel weight" of 0 or 8 (corresponding to 0 or 8 surrounding black pels).

A correct match is considered to have occurred if the whole error picture can be processed without rejection.

Since nine template matches are made between two symbols, there are at times two or more alignments that lead to a correct match. In that case, the position which has the lowest count of the sum of the error weights is chosen.

4. CODING AND LIBRARY UPDATING

4.1 Coding of the Position of a Symbol

The first codeword for a symbol is its position. A special position codeword 111 indicates that there are no more symbols on the line. Any codeword not starting with 111 can be used to indicate the position of a symbol. The horizontal and vertical positions of each symbol are coded. The reference point is upper

left corner of the block that contains the symbol.

The absolute horizontal position of each symbol is coded by eleven bit two's complement binary. Variable length run-length coding is not justified since the distance between the symbols and the edge of the document is typically long.

The symbols can be transmitted in a nonsequential order. Reordering has been found to lead to a significant decrease in the average code length for the library identification codewords.

With 1792 pels/line, an 11 bit binary codeword can code the horizontal position of a symbol without using any codeword that starts with 111.

The vertical position of a symbol is coded in the following way:

a. A mode bit at the beginning of each line indicates whether there are any symbols on the line. The mode bit is 0 if any symbol is detected on the line. It is 1 if no symbols are detected.

b. The symbols on a line are coded and are followed by the codeword 111 which indicates that there are no more symbols on the line.

c. When a symbol is replaced by a library symbol, the position of the library symbol might move up or down one position. Therefore, after the library identification has been coded, the codewords 10 and 11 are used to position the library symbol up or down respectively. The codeword 0 is used to indicate no vertical displacement. The vertical displacement codeword is not sent with a new library symbol.

Figure 12 shows examples of the message format for the symbol positioning.

4.2 Coding of the Library Symbol Description

A symbol must fit within a 32x32 pel block. The description of the symbol starts with a 5 bit binary word which indicates the height H of a pattern. The length of a pattern is extended to 32 pels if necessary by appending 0's to the right end. Therefore, there are 32xH pels to code. For coding efficiently, one white pel ("0") is added at the beginning.

A coding line is made from the 32xH+1 pels which are aligned in raster scan order. The reference line is similar to the coded line except that all the pels are shifted to the right by 32 pels (one line). Therefore, the pel on the coding line has the same column coordinate as the pel on the line above has on the reference line. The line is then coded by the CCITT Modified Read Algorithm, with the only modification that the first code word, which is always the horizontal mode code word, is deleted since it is not necessary. For coding efficiency, switching is allowed between two modes for the coding of the library symbol description. The first mode is

the described above called "horizontal coding." The other is called "vertical coding" and is the same as above except that the symbol is coded column after column from top to bottom.

A header bit indicates which mode is chosen with a "0" for horizontal mode and a "1" for vertical mode. It is followed by a 5 bit word which indicates the length of a symbol.

4.3 Coding of the Symbol Identification

A codeword is sent for each new symbol to indicate which library symbol has produced a match. If the symbol number is coded in two's complement binary, 9 bits would be required for a library with 512 symbols.

The coding procedure described here leads to an average coding length of less than 5 bits/symbol. This result is obtained by a continuous library updating and variable length coding.

4.3.1 *Library Updating and Management* Library management and updating is done for the following purposes:

a. Accept new library symbols, and, if necessary, delete a seldom used library symbol to make place for the new one.

b. Organize the library for the fastest possible match.

c. Organize the library for minimum average library identification coding length.

All three purposes require keeping track of the number of times each library symbol is used. A correct match can be obtained rapidly if the library symbols are ordered in decreasing usage. This way the most used library symbols will be accessed first. An efficient coding of the symbols identification is obtained by giving short codewords to the first symbols in the list. The last symbol in the list, which is one of the least used symbols, can be deleted to make place for a new symbol.

The updating rule for the symbols in the library is as follows:

a. When a symbol matches a library symbol number K, that library symbol is moved to number K/2 and all the symbol numbers from K/2 to K-1 are increased by 1.

b. When a new symbol is added, it gets number N/2 where N is the number of library symbols. The symbols with numbers from N/2 to N will be increased by 1, and if necessary, the last library symbol is dropped.

This updating procedure has been found to be efficient in giving low identification numbers to often used symbols.

The updating and coding is only done at the end of each scan line. A library symbol will be moved only once on a line, even if it matches several incoming symbols on the line.

4.3.2 *Symbol Identification Coding Table* The symbol identification code table includes two special codewords: new symbol and same symbol. The "new symbol" codeword makes it unnecessary to send an identification number for a new library symbol. The "same symbol" codeword indicates that the transmitted symbol is the same as the previously transmitted symbol. It is useful particularly for typewritten text where the line by line search for a symbol often detects the same symbols (character on a line).

The code table for the symbol identification is given in Table 1.

Experience has shown that without sorting this code leads to an average library identification code length of less than 7 compared to 9 that obtains for a fixed length code. These results are based on the 8 CCITT documents. Sorting which is described in the next section further reduces the code length.

4.3.3 *Symbol Identification Coding and Sorting* The absolute code for the horizontal position of a symbol allows symbols detected along a line to be transmitted in any order. A precondition is that the library updating must be done only at the end of the line. By sorting the symbols on a line according to their library number, the average coding length of the library identification has been found to be less than 5. This obtains because: 1) there are many more identical symbols; 2) the library symbol is run length coded and 3) the new library symbols are sent at the end. Therefore, the new symbol codeword is sent only once on a line since if there are more symbols, they are automatically new symbols.

This can be illustrated by an example: let a line have the following symbols: symbol 23, new symbol, symbol 28, same, symbol 23, new symbol.

> By looking at Table 1, the coding length is 7 + 5 + 7 + 3 + 7 + 5 = 34 bits. With sorting, the symbols become: symbol 23, same, symbol 28, same, new symbol, new symbol. The coding length is 7 + 3 + 5 + 3 + 5 + 0 = 23 bits. It should be noted in this example that symbol 28 is coded as symbol 5 since only the increase in ID number compared to the previous symbol is coded.

4.4 Coding Summary

The coding procedure can be summarized in the following way:

1. All the symbols isolated along a line are matched (see sections 2 and 3).

2. At the end of the line, the matched symbol are sorted in order of increasing symbol identification number. The new library symbols are added at the end in sequential order (see section 4.3.1).

3. The symbols are coded with the information sent in the following order:

a. Horizontal position of symbol (see section 4.1).

b. Symbol identification. If it is a new symbol, the identification is sent only for the first new symbol on the line (see section 4.3.2).

c. A 1 or 2 codeword bits to specify the vertical shift of a symbol except if it is a new library symbol (see section 4.1).

d. For a new library symbol the following information is sent. (see also section 4.2).

   - A header bit indicating whether the horizontal or vertical coding mode is chosen.

   - A 5 bit word indicating the number of lines of the symbol to be coded.

   - CCITT Modified Read coding of the symbol

e. After all symbols on a line have been sent, the special horizontal codeword 111 indicates the end of the line (see section 4.1).

f. The library update is made according to the updating rule in 4.3.1. The symbols are updated in order of increasing ID number. After updating, all symbols with number greater than 480 are deleted, thus allowing for at least 32 new library symbols to be added on next line. In the rare cases where more than 32 new symbols are encountered on a line, the library will overflow. The problem is resolved by introducing an artificial new line. The portion of the existing line that has already been coded is terminated in the usual way. The library will be flushed to 480 symbols. The artificial new line will start with a special horizontal codeword 111 which is an indication that it is an artificial line. Symbols will be added to the library again as needed.

Figure 13 gives an example of message transmission. Table 2 summarizes the different codewords that are sent.

5. DECODER

A pattern matching decoder is inherently simpler than a pattern matching encoder. In principle, all the decoder has to do is to reproduce symbols on the decoded image plane. The source of the symbols is either the symbol library when a symbol identification number is detected in the code stream, or the pel description of a new symbol which is embedded in the code stream. The decoder is completely independent of the matching algorithm that is used in the encoder.

Our experience has shown that image quality is often improved by slightly modifying certain decoded symbols. If a symbol is 30 pels or more high or wide, the symbol is expanded by two pel on the high or wide side. This is accomplished by doubling the row or column three pels away from each border. This modification corrects small distortions which can occur in large pattern regions of the image. In addition, a local 3 by 3 postprocessing is found useful in eliminating the artifacts in large black regions. The postprocessor replaces a white pel by a black pel if the columns to its left and to its right are black, or the row above and below are black.

Experience has also shown that the image quality of decoded images can be often improved by additional post processing operations. The decoder may produce small edge discontinuities where it is matching up symbols to form a large pattern. While any individual error is small, the human eye is very sensitive to the resulting jagged edges. The edge discontinuity can usually be reduced by post processing. Post processing algorithms are well known in the facsimile literature and are not an inherent part of the decoder. Therefore the choice of a post processor is left as a manufacturer's option.

APPENDIX 2: RESULTS

This appendix gives results of the coding simulations. We used for our simulations a digitized version of the 8 CCITT documents which was supplied by the French administration. The page format was 1728 x 2376 pels.

1. FACSIMILE QUALITY

The binary picture is modified slightly by the coder. An acceptable coder must not produce alterations that are annoying or noticeably visible.

There are three types of alterations that can result from pattern coding: wrong matches, matches with a slightly distorted pattern and wrong positioning. In the case of a wrong match, a pattern is replaced by a different pattern. The only wrong matches we found were confusions between O and 0, dot and comma, I and 1. Even human observers have difficulty recognizing these patterns correctly out of context. Therefore, it can be considered that the system has practically no wrong matches.

A match with a slightly distorted pattern can occur with characters. A character might match a different font version of the same character. Alternatively, a character might match a thinned version of the same or thickened character. Distorted matches, contrary to wrong matches, are tolerable if they don't appear too often. They commonly appear when two slightly different fonts are used on a page or when the digitized characters come from a low quality typewriter or scanner.

Wrong positioning of a pattern decreases received copy quality. We observed no wrong positioning for characters or other symbols. Some wrong positioning has been observed for non symbol patterns such as line segments, where the successive patterns make the lines slightly jagged.

Figures 2 through 9 show the CCITT facsimile images after pattern matching coding and subsequent decoding. It can be seen that there are no significant degradations. Some slight irregularities in line drawings are observed, as for example in CCITT document 5 (Figure 6). A few "distored matches" appear on CCITT document 1 (Figure 2).

2. COMPRESSION

Table 3 gives the coding lengths for the CCITT documents which result from the AT&T which pattern matching algorithm and from the Modified Read Code. Table 4 gives the transmission time at 64 kbits/s. Table 5 gives the compression ratio for the eight documents. The results were obtained without the use of any synchronization or stuffing bits.

On the average, the transmission time is reduced by 47 percent compared to the Modified Read Code. The decrease in transmission time compared to the Modified Read Algorithm is variable. For documents containing mostly handwritten drawings and text, such as documents 2 and 8, there can be a slight increase in the number of code bits. This obtains because there are few matching patterns. For example, for document 2 there are 716 patterns, but 459 of them are library patterns. For documents containing mostly text, such as document 4, the transmission time is reduced nearly by a factor 5. For documents containing a mixture of text and drawings, the transmission time is reduced by 30 to 45 percent. For document 7, the decrease is smaller than for regular printed text because the number of Chinese characters and hence symbols far exceeds the number of symbols that would be found on a typed letter. However, the AT&T pattern matching algorithm still doubled the compression ratio.

APPENDIX 3: EXTENSIONS

This appendix shows how the proposed pattern matching coding technique can be extended to pages wider than 1792 pels and resolutions higher than 200 pels/inch. It also shows how the coder can control the amount of distortion that will occur during the coding process. Finally, coding efficiency can in many cases be improved if a prestored library can be used to start the coding process.

1. EXTENSIONS TO DOCUMENTS WIDER THAN 1792 PELS

The restriction that the suffix code 111 be reserved when coding the horizontal position using eleven bit two's complement binary restricts the page width to 1792 pels. For larger documents, the 11 bit codeword is replaced by a longer one. For example, a 12 or 13 bit horizontal code allows lines as wide as 3584 and 7168 pels respectively.

The maximum width of the document being coded would be made known to the decoder via protocol.

2. EXTENSIONS TO HIGHER RESOLUTION DOCUMENTS

The relative advantage of the AT&T pattern matching coding algorithm over the standard Modified Read algorithm increases with increased resolution. The number of code bits produced by the Modified Read algorithm increases approximately linearly with increased resolution. Pattern matching generates code which consists of two components. One part is the symbol description which is based on Modified Read code and therefore generates code which increases linearly with resolution. The other part is the symbol identification and position information that is only weakly dependent on resolution. The net effect is that the number of code bits generated by the pattern matching algorithm will increase much less with increased resolution than would the code bits generated by the Modified Read algorithm.

The extension of the pattern matching algorithm to higher resolution requires a few changes in the coding algorithm to work efficiently. One change comes about because the line lengths are typically longer at higher resolution. The solution to this problem was treated above. Another change comes about because it is advantageous to increase the block size to fit the size of the pattern. It follows that a block size of 48x48 would be effective for 300 pels/inch. Similarly, a block size of 64x64 would be good for 400 pels/inch. The codeword used to indicate the size of a symbol for a block size of up to 64x64 would need to be increased to 6 bits. Larger block sizes would result in correspondingly larger symbol size description codes.

The coder would let the decoder know the maximum block size via protocol.

3. CONTROL OVER CODER DISTORTION

There might be some cases where coding with practically no distortion is preferred. It is possible to improve the image quality by tightening the matching criteria. In that case the coder simply tightens the rejection criteria when it compares an unknown symbol with a symbol in the library. For example, the coder can reject any match with weight 3 or greater instead of of 4 or greater as was proposed in Appendix 1.

The matching criteria is local to the coder. Therefore the coder does not need to inform the decoder about the details of the matching criteria.

4. PRESTORED LIBRARIES

Considerable improvement in coding efficiency is possible if the coder starts out coding a new page from a prestored code library. This reduces the number of patterns that need to be sent to the decoder to fill up the decoder's library. Prestored libraries are not practical for arbitrary images because the symbols in the library need to be closely matched to image content.

Prestored libraries are useful in two cases. The first is where the character font is known a priori by the encoder. In this case, the starting code library would also be known to the encoder. This library would be communicated to the decoder via protocol. A special case is where the decoder also has prestored libraries for a variety of different fonts. In that case, only the font style need be corresponded to the decoder.

A second case obtains for multi-page documents. In that situation, it is usually best to code the next page starting with the library developed at the conclusion of coding the last page. This situation would also be communicated to the decoder via protocol.

Symbol	Codeword	Codeword length
same symbol	000	3
library symbol 1-16	1XXXX	5
new symbol	00100	5
library symbol 17-32	010XXXX	7
library symbol 33-64	0011XXXXX	9
library symbol 65-128	00101XXXXXX	11
library symbol 129-512	011XXXXXXXXX	12

Table 1: Coding Table for the identification of the library symbols where XXXX is coded as Two's Complement Binary (see section 4.3.2).

Table 2: Description of the Codewords for Pattern Matching Coding (Maximum Page Width 1792 pels)

Code Definition	*Word Size*	*Description*
Mode bit	1	Indicate whether there are any symbols on the line. The mode bit is 0 if any symbols are detected, 1 if none are (see section 4.1).
Horizontal position	11	Gives in two's complement binary the absolute position of a symbol (see section 4.1).
No more symbol	3	111 Indicates that there are no more symbols on the line (this codeword: 111 is a special horizontal position codeword) (see section 4.1).
Vertical move of symbol	1 or 2	Indicates whether the symbol must be moved up (codeword 10) or down (codeword 11) by one line or is not moved at all (codeword 0) (see section 4.1).
Library identification code	variable	Define which library symbol is coded (see Table 1 for coding).
Library symbol description header	1	Indicate whether the library symbol is coded in horizontal (header 0) or vertical (header 1) mode (see section 4.2).
Library symbol size	5	Gives in two's complement binary the number of lines which must be coded by the library symbol description code (see section 4.2).
Library symbol description	variable	Slightly modified CCITT Modified Read code (see section 4.2).

Document	Pattern Matching Code	Modified Read Code	Reduction in number of bits coded
CCITT1	65426	144816	54.8%
CCITT2	89219	86416	-3.3%
CCITT3	158424	229639	31.0%
CCITT4	116140	554186	79.0%
CCITT5	141107	257767	45.3%
CCITT6	105982	133197	20.4%
CCITT7	269070	554247	51.5%
CCITT8	182509	152786	-19.5%
Total	1127877	2133052	47.1%

Table 3: Comparison of number of bit coded.

Document	Pattern Matching Code	Modified Read Code
CCITT1	1.02s	2.26s
CCITT2	1.39s	1.35s
CCITT3	2.48s	3.59s
CCITT4	1.81s	8.66s
CCITT5	2.20s	4.03s
CCITT6	1.66s	2.08s
CCITT7	4.20s	8.66s
CCITT8	2.85s	2.39s
Total	17.6s	33.0s

Table 4: Comparison of transmission times at 64 Kbits/s.

Document	Pattern Matching Code	Modified Read Code
CCITT1	62.75	35.28
CCITT2	46.02	47.51
CCITT3	25.92	17.88
CCITT4	35.35	7.41
CCITT5	29.10	15.93
CCITT6	38.74	30.82
CCITT7	15.26	7.41
CCITT8	22.50	26.87

Table 5: Comparison of Compression Ratios

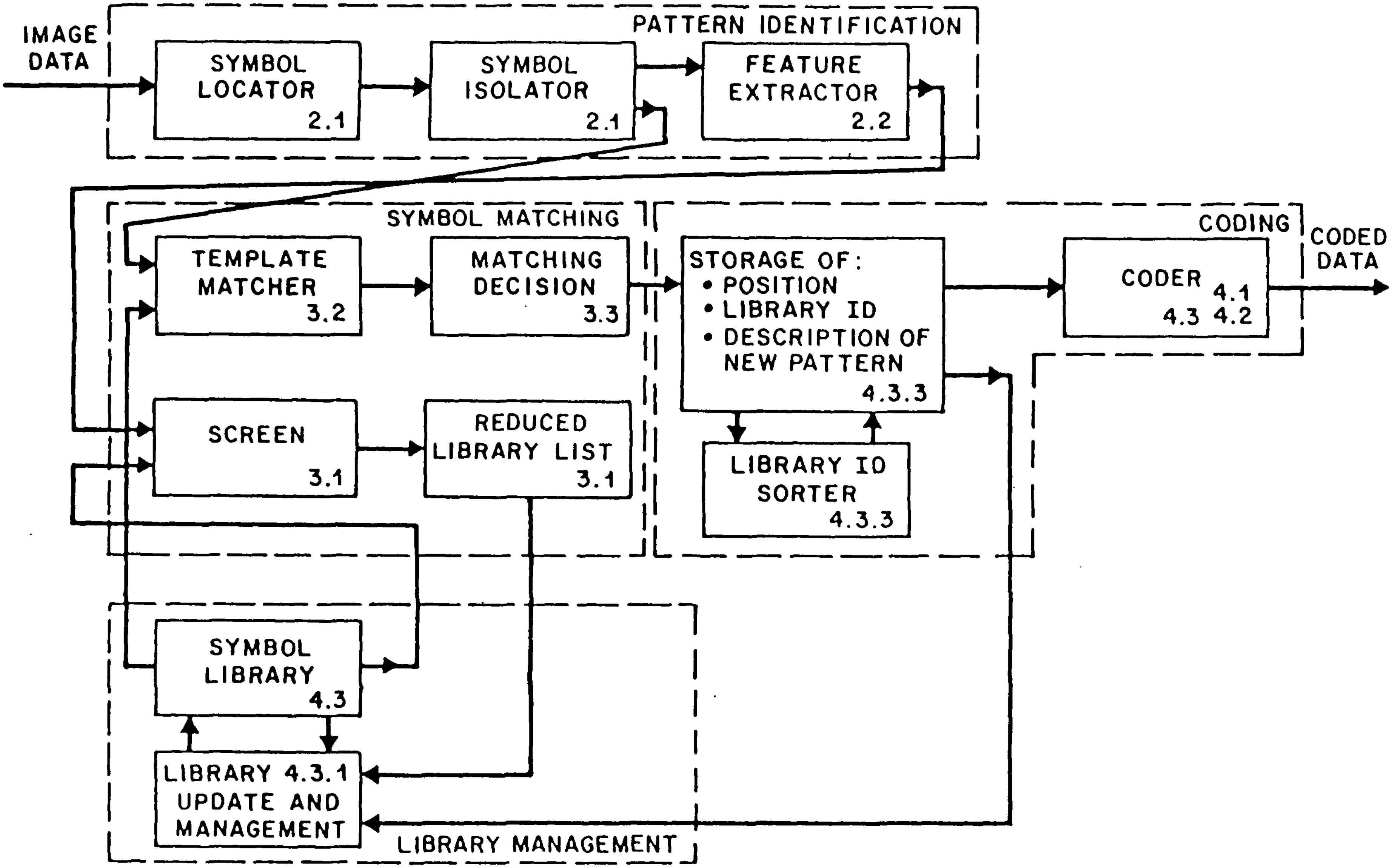


FIGURE 1 BLOCK DIAGRAM OF THE ATT PATTERN MATCHING CODER. THE NUMBERS REFERS TO THE SECTIONS OF APPENDIX 1

THE SLEREXE COMPANY LIMITED

SAPORS LANE - BOOLE - DORSET - BH 25 8 ER

TELEPHONE BOOLE (945 13) 51617 - TELEX 123456

Our Ref. 350/PJC/EAC 18th January, 1972.

Dr. P.N. Cundall,
Mining Surveys Ltd.,
Holroyd Road,
Reading,
Berks.

Dear Pete,

Permit me to introduce you to the facility of facsimile transmission.

In facsimile a photocell is caused to perform a raster scan over the subject copy. The variations of print density on the document cause the photocell to generate an analogous electrical video signal. This signal is used to modulate a carrier, which is transmitted to a remote destination over a radio or cable communications link.

At the remote terminal, demodulation reconstructs the video signal, which is used to modulate the density of print produced by a printing device. This device is scanning in a raster scan synchronised with that at the transmitting terminal. As a result, a facsimile copy of the subject document is produced.

Probably you have uses for this facility in your organisation.

Yours sincerely,

Phil.

P.J. CROSS
Group Leader - Facsimile Research

Figure 2: Document 1 after pattern matching coding and decoding.

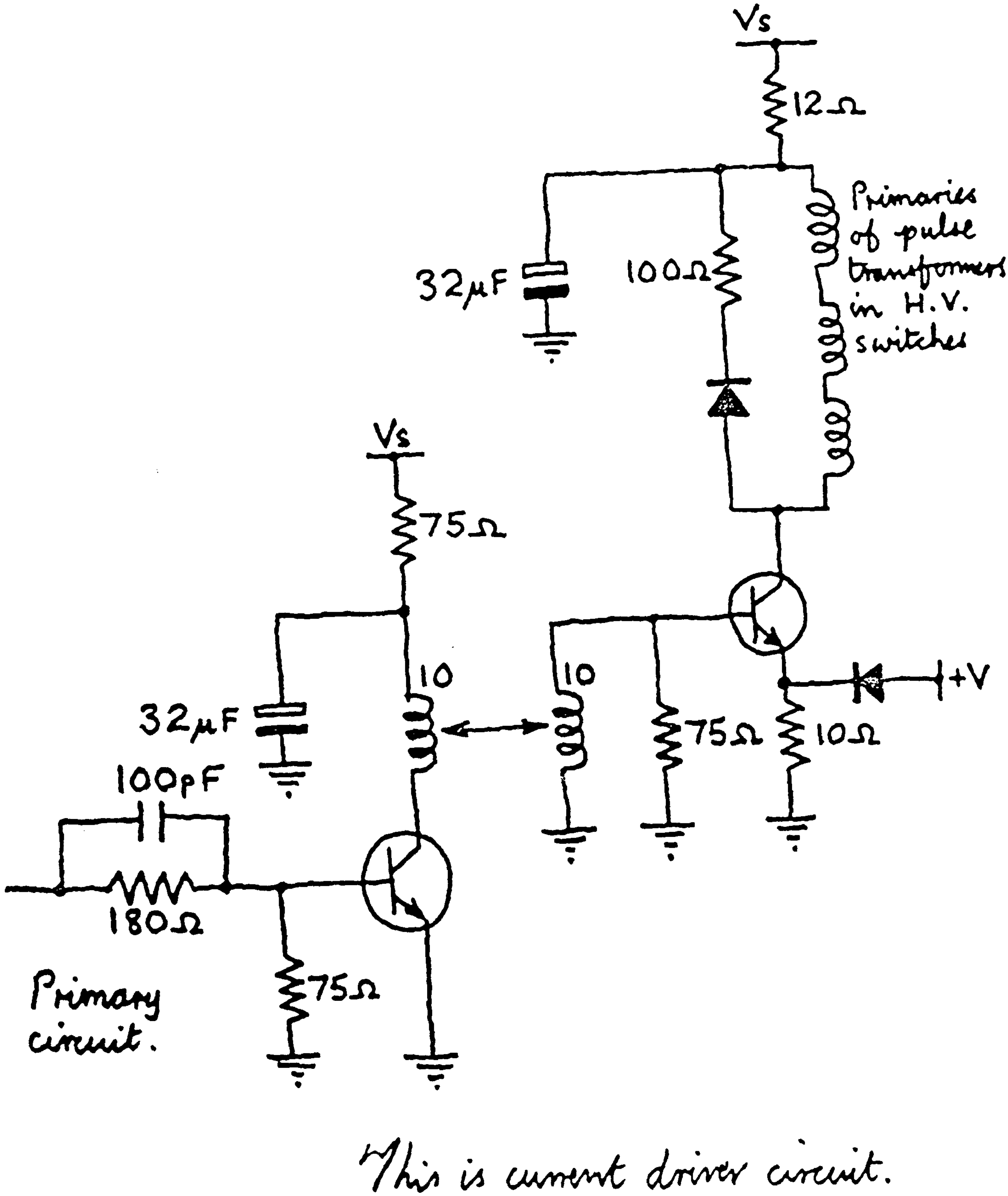


Figure 3: Document 2 after pattern matching coding and decoding.

ETABLISSEMENTS ABCDEFG
SOCIETE ANONYME AU CAPITAL DE 300 000 F
30, RUE DU XYUTRSTESL F 00000 NTBCLAG
Tél. : (35) 34.46.32 Adr. Tg. : NRVLUROLM
Télex : 31500 F IN : 7164900070257
Transporteur (ou Transitaire)
M. M. DUPONT Frères
8 quai des blodfsh F 0000 NTBCLAG

Mot directeur

CLASSEMENT	FACTURE INVOICE		Exemplaire 15
CODE CLIENT Z 04599	DATE 7-7-74	NUMERO 06	FEUILLET 01

Votre commande du 74-2-2 numéro 438

Notre offre AZ/B7 du 74-1-1 numéro 12

LIVRAISON
5, rue XYZ
99000 VILLE

FACTURATION
12, rue ABCD BP 15
99000 VILLE

DOMICILIATION BANCAIRE DU VENDEUR

CODE BANQUE CODE GUICHET COMPTE CLIENT

ORIGINE	TRANSPORTS DESTINATION	MODE
Pays 1	Etat 2	Air

PAYS D'ORIGINE PAYS DE DESTINATION

CONDITIONS DE LIVRAISON DATE 74-03-03

LICENCE D'EXPORTATION NATURE DU CONTRAT (monnaie)

CONDITIONS DE PAIEMENT FAB (échéance, %...)

MARQUES ET NUMEROS MARKS AND NUMBERS	NOMBRE ET NATURE DES COLIS : DENOMINATION DE LA MARCHANDISE NUMBER AND KIND OF PACKAGES: DESCRIPTION OF GOODS	NOMENCLATURE STATISTICAL No.	MASSE NETTE NET WEIGHT MASSE BRUTE GROSS WEIGHT	VALEUR VALUE DIMENSIONS MEASUREMENTS
74.21.456.44.2 A	1 Composants	U 123/4	5 kg 8 kg	1400 X 13x10x6

QUANTITE COMMANDEE ET UNITE QUANTITY ORDERED AND UNIT	N° ET REF. DE L'ARTICLE	DESIGNATION	QUANTITE LIVREE ET UNITE QUANTITY DELIVERED AND UNIT	PRIX UNITAIRE UNIT PRICE	MONTANT TOTAL TOTAL AMOUNT
2	AF-809	Circuit intégré	2	104,33 F	208,66 F
10	88-T4	Connecteur	10	83,10 F	831,00 F
25	ZI07	Composant indéterminé	20	15,00 F	300,00 F

Figure 4: Document 3 after pattern matching coding and decoding.

L'ordre de lancement et de réalisation des applications fait l'objet de décisions au plus haut niveau de la Direction Générale des Télécommunications. Il n'est certes pas question de construire ce système intégré "en bloc" mais bien au contraire de procéder par étapes, par paliers successifs. Certaines applications, dont la rentabilité ne pourra être assurée, ne seront pas entreprises. Actuellement, sur trente applications qui ont pu être globalement définies, six en sont au stade de l'exploitation, six autres se sont vu donner la priorité pour leur réalisation.
Chaque application est confiée à un "chef de projet", responsable successivement de sa conception, de son analyse-programmation et de sa mise en oeuvre dans une région-pilote. La généralisation ultérieure de l'application réalisée dans cette région-pilote dépend des résultats obtenus et fait l'objet d'une décision de la Direction Générale. Néanmoins, le chef de projet doit dès le départ considérer que son activité a une vocation nationale donc refuser tout particularisme régional. Il est aidé d'une équipe d'analystes-programmeurs et entouré d'un "groupe de conception" chargé de rédiger le document de "définition des objectifs globaux" puis le "cahier des charges" de l'application, qui sont adressés pour avis à tous les services utilisateurs potentiels et aux chefs de projet des autres applications. Le groupe de conception comprend 6 à 10 personnes représentant les services les plus divers concernés par le projet, et comporte obligatoirement un bon analyste attaché à l'application.

II - L'IMPLANTATION GEOGRAPHIQUE D'UN RESEAU INFORMATIQUE PERFORMANT

L'organisation de l'entreprise française des télécommunications repose sur l'existence de 20 régions. Des calculateurs ont été implantés dans le passé au moins dans toutes les plus importantes. On trouve ainsi des machines Bull Gamma 30 à Lyon et Marseille, des GE 425 à Lille, Bordeaux, Toulouse et Montpellier, un GE 437 à Massy, enfin quelques machines Bull 300 TI à programmes câblés étaient récemment ou sont encore en service dans les régions de Nancy, Nantes, Limoges, Poitiers et Rouen ; ce parc est essentiellement utilisé pour la comptabilité téléphonique.
A l'avenir, si la plupart des fichiers nécessaires aux applications décrites plus haut peuvent être gérés en temps différé, un certain nombre d'entre eux devront nécessairement être accessibles, voire mis à jour en temps réel : parmi ces derniers le fichier commercial des abonnés, le fichier des renseignements, le fichier des circuits, le fichier technique des abonnés contiendront des quantités considérables d'informations.
Le volume total de caractères à gérer en phase finale sur un ordinateur ayant en charge quelques 500 000 abonnés a été estimé à un milliard de caractères au moins. Au moins le tiers des données seront concernées par des traitements en temps réel.
Aucun des calculateurs énumérés plus haut ne permettait d'envisager de tels traitements.
L'intégration progressive de toutes les applications suppose la création d'un support commun pour toutes les informations, une véritable "Banque de données", répartie sur des moyens de traitement nationaux et régionaux, et qui devra rester alimentée, mise à jour en permanence, à partir de la base de l'entreprise, c'est-à-dire les chantiers, les magasins, les guichets des services d'abonnement, les services de personnel etc.
L'étude des différents fichiers à constituer a donc permis de définir les principales caractéristiques du réseau d'ordinateurs nouveaux à mettre en place pour aborder la réalisation du système informatif. L'obligation de faire appel à des ordinateurs de troisième génération, très puissants et dotés de volumineuses mémoires de masse, a conduit à en réduire substantiellement le nombre.
L'implantation de sept centres de calcul interrégionaux constituera un compromis entre : d'une part le désir de réduire le coût économique de l'ensemble, de faciliter la coordination des équipes d'informaticiens; et d'autre part le refus de créer des centres trop importants difficiles à gérer et à diriger, et posant des problèmes délicats de sécurité. Le regroupement des traitements relatifs à plusieurs régions sur chacun de ces sept centres permettra de leur donner une taille relativement homogène. Chaque centre "gèrera" environ un mil-

Figure 5: Document 4 after pattern matching coding and decoding.

Cela est d'autant plus valable que $T\Delta f$ est plus grand. A cet égard la figure 2 représente la vraie courbe donnant $|\phi(f)|$ en fonction de f pour les valeurs numériques indiquées page précédente.

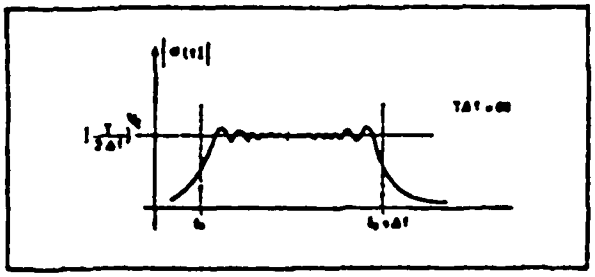


FIG. 2

Dans ce cas, le filtre adapté pourra être constitué, conformément à la figure 3, par la cascade :

— d'un filtre passe-bande de transfert unité pour $f_0 \leq f \leq f_0+\Delta f$ et de transfert quasi nul pour $f < f_0$ et $f > f_0+\Delta f$, filtre ne modifiant pas la phase des composants le traversant ;

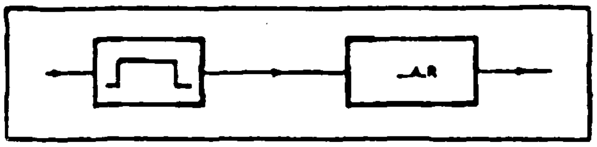
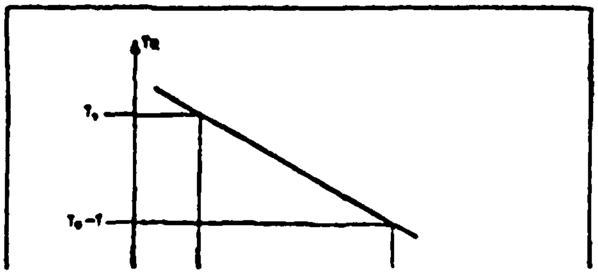


FIG. 3

— filtre suivi d'une ligne à retard (LAR) dispersive ayant un temps de propagation de groupe T_R décroissant linéairement avec la fréquence f suivant l'expression :

$$T_R = T_0+(f_0-f)\frac{T}{\Delta f} \quad (\text{avec } T_0 > T)$$

(voir fig. 4).



telle ligne à retard est donnée par :

$$\varphi = -2\pi \int_0^f T_R \, df$$

$$\varphi = -2\pi \left[T_0 + \frac{f_0 T}{\Delta f} \right] f + \pi \frac{T}{\Delta f} f^2$$

Et cette phase est bien l'opposé de $\underline{/\phi(f)}$.

à un déphasage constant près (sans importance) et à un retard T_0 près (inévitable).

Un signal utile $S(t)$ traversant un tel filtre adapté donne à la sortie (à un retard T_0 près et à un déphasage près de la porteuse) un signal dont la transformée de Fourier est réelle, constante entre f_0 et $f_0+\Delta f$, et nulle de part et d'autre de f_0 et de $f_0+\Delta f$, c'est-à-dire un signal de fréquence porteuse $f_0+\Delta f/2$ et dont l'enveloppe a la forme indiquée à la figure 5, où l'on a représenté simultanément le signal $S(t)$ et le signal $S_1(t)$ correspondant obtenu à la sortie du filtre adapté. On comprend le nom de récepteur à compression d'impulsion donné à ce genre de filtre adapté : la « largeur » (à 3 dB) du signal comprimé étant égale à $1/\Delta f$, le rapport de compression est de $\frac{T}{1/\Delta f} = T\Delta f$

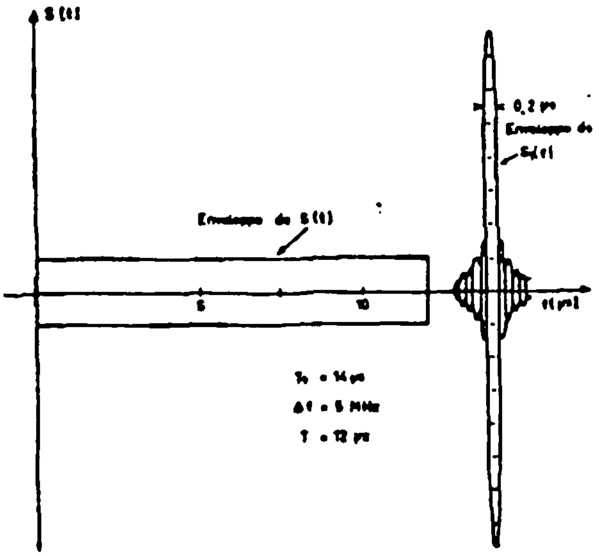


FIG. 5

On saisit physiquement le phénomène de compression en réalisant que lorsque le signal $S(t)$ entre dans la ligne à retard (LAR) la fréquence qui entre la première à l'instant 0 est la fréquence basse f_0,

Figure 6: Document 5 after pattern matching coding and decoding.

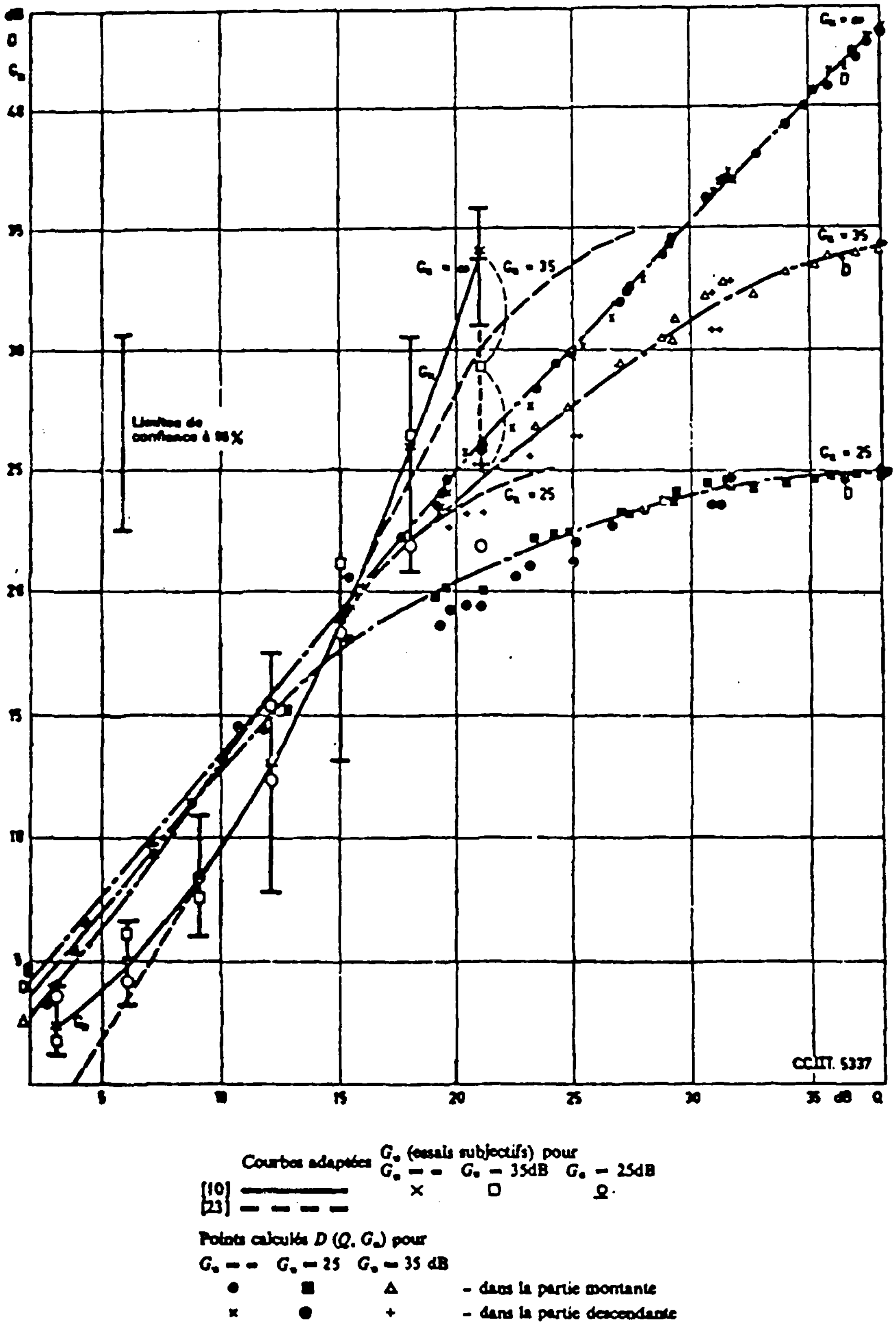


Figure 7: Document 6 after pattern matching coding and decoding.

CCITTの概要

沿革

CCITTは、国際電気通信連合（ITU）の四つの常設機関（事務総局、国際周波数登録委員会、CCIR、CCITT）の一つとして、ITUの中でも、世界の国際通信上の諸問題を真先に取上げ、その解決方法を見出して行く重要な機関である。日本名は、国際電信電話諮問委員会と称する。

CCITTの前身は、CCIF（国際電話諮問委員会）とCCIT（国際電信諮問委員会）である。CCIFは、1924年にヨーロッパに「国際長距離電話通信諮問委員会」が設置され、これが1925年のパリ電信電話会議のとき、正式に、「国際電話諮問委員会」として万国電信連合の公式機関となったものである。CCITは、同じく1925年の会議のとき、CCIFと併立するものとして設置された。

そして、CCIFは、1956年の12月に第18回総会が開催されたのち、CCITは、同年同月に第8回総会が開催されたのち、併合されて現在のCCITTとなった。このCCITTは、CCIFとCCITが解散した直後、第1回総会を開催し、第2回総会は、1960年にニューデリーで、第3回総会は、1964年、ジュネーブで、第4回総会は、1968年、アルゼンチンで開催された。

CCIFとCCITが合併したのは、有線電気通信の分野、とくに伝送路について電信回線と電話回線とを技術的に分ける意味がなくなってきたこと、各国とも大体において、電信部門と電話部門は同一組織内にあること、CCIFの事務局とCCITの事務局の合併による能率増進等がおもな理由であった。

CCITTは、上述のように、ヨーロッパ内の国ぐにによって、ヨーロッパ内の電信・電話の技術・運用・料金の基準を定め、あるいは統一をはかってきたので、現在でも、その影響を受け、会合参加国は、ヨーロッパの国が多く、ヨーロッパで生起する問題の研究が多い。たとえば、1960年のCCITT勧告の中で、技術上配慮する距離は約2,500㎞であったが、これはヨーロッパ内領域を想定したものである。

しかしながら、1956年9月に敷設された大西洋横断電話ケーブルは、大陸間電話通信の自動化および半自動化への技術的可能性を与え、CCITTがこの問題を取り上げるに及び、CCITTの性格は膨大、汎世界的色彩を実質的に帯びるに至った。この汎世界的性格は第2次世界大戦後目ざましくなったアジア・アフリカ植民地の独立に伴ってITUの構成員の中にこれらの国が加わり、ITUの中に新しい意見が導入されたことにも起因して、技術面、政治面の双方から導入されてきた。CCITTの汎世界化は、1960年の第2回総会がニューデリーで開催されたことにもあらわれている。この総会までは、CCIT、CCIFおよびCCITTの総会がアメリカやアジアで開催されたことがなく、CCITT総会の準備文書で、この点には注目すべきであるとのべている。

任務

ITUは、全権委員会議、主管庁会議を始めとして、七つの機関の権限と任務は国際電気通信条約に明記されている。これの中から、CCITTの任務を見てみるならば、つぎのとおりとなっている。

「国際電信電話諮問委員会(CCITT)は、電信および電話の技術、運用および料金の問題について研究し、および意見を表明すること」（1965年モントルー条約第187号）

「各国際諮問委員会は、その任務の遂行に当たって、新しい国における地域的および国際的分野にわたる電気通信の発達に直接関連のある問題について研究し、および意見を作成することに妥当な注意を払わなければならない。」（同第188号）

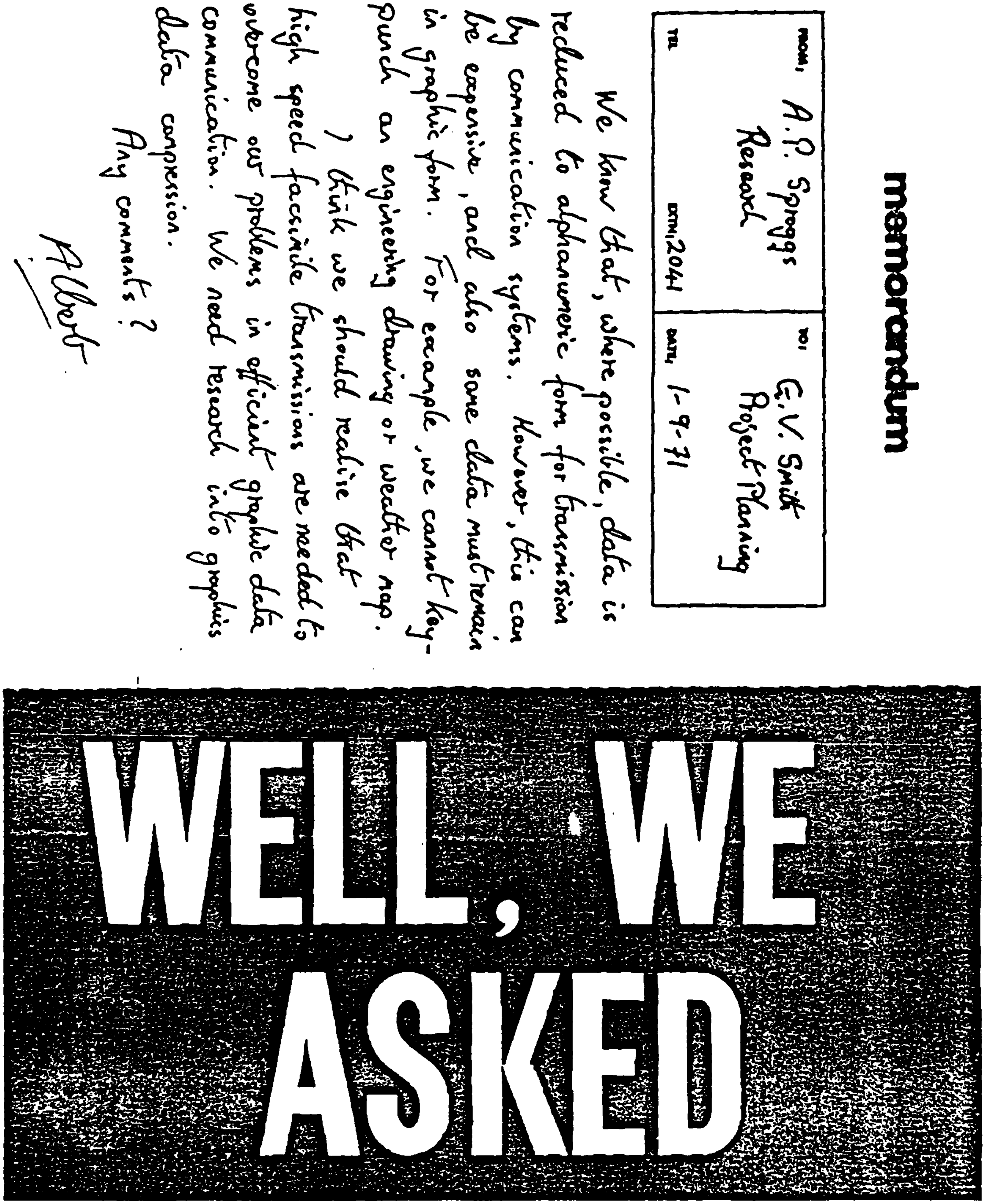
「各国際諮問委員会は、また、関係国の要請に基づき、その国の問題について研究し、かつ、勧告を行なうことができる。」（同第189号）

上記第187号と第188号にいわれる「意見」とは、フランス語を訳したもので、英語では、「勧告(Recommendation)」となっており、意見を表明する意見は、国際法的には強制力をもたないものであって、電信規則、電話規則等各国を拘束する力をもっているものと異なる。意見は称しても、技術的分野では、電信規則のごとき、各国政府が実施する強制規則をもたないので、実際にある機器の仕様を定める各国の意見が統一されたこの「意見」に従わなければ、円滑な通信ができない場合が多い。この意見（または勧告）は、国際通信が直面する問題について、具体的意見を表明するもので、たとえば大陸間通話を半自動化しようとする場合、その信号方式や料金は、どのようにするかを研究して意見を表明する。

CCITTの活動は、つねに時代の最先端を行くもので、CCITTのまま世界の国際通信の活動方向であるともいえる。

この意見は、また、電信規則以下のその他の規則のごとく、数年おきに開催される主管庁会議というような大会議の決定をまたなければならないということがなく、その改正も容易であるので、現在のように進歩が早い分野においては、関係国の意見を統一した国際的見解としては非常に便利で、

Figure 8: Document 7 after pattern matching coding and decoding.


memorandum

FROM: A.P. Spriggs
Research

TO: G.V. Smith
Project Planning

TEL: EXTN. 2041

DATE: 1-9-71

We know that, where possible, data is reduced to alphanumeric form for transmission by communication systems. However, this can be expensive, and also some data must remain in graphic form. For example, we cannot key-punch an engineering drawing or weather map.

I think we should realise that high speed facsimile transmissions are needed to overcome our problems in efficient graphic data communication. We need research into graphics data compression.

Any comments?

Albert

Figure 9: Document 8 after pattern matching coding and decoding.

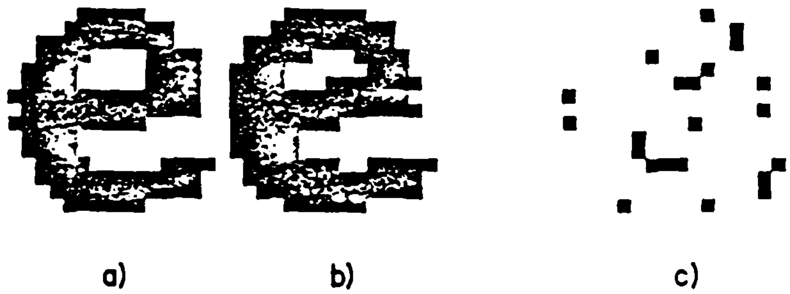


FIGURE 10 TEMPLATE MATCHING OF TWO SIMILAR SYMBOLS WITH a) AND b) ORIGINAL SYMBOL AND c) ERROR PICTURE.

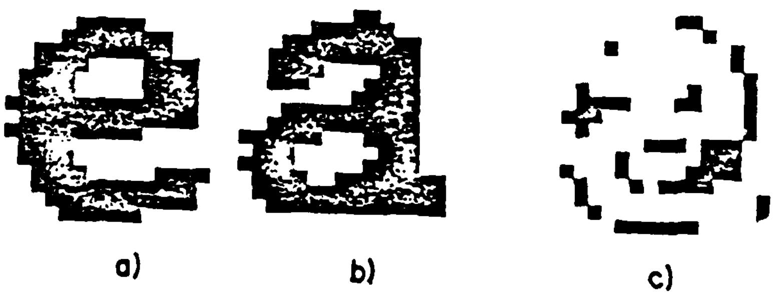


FIGURE 11 TEMPLATE MATCHING OF TWO DIFFERENT SYMBOLS WITH a) AND b) ORIGINAL SYMBOL AND c) ERROR PICTURE.

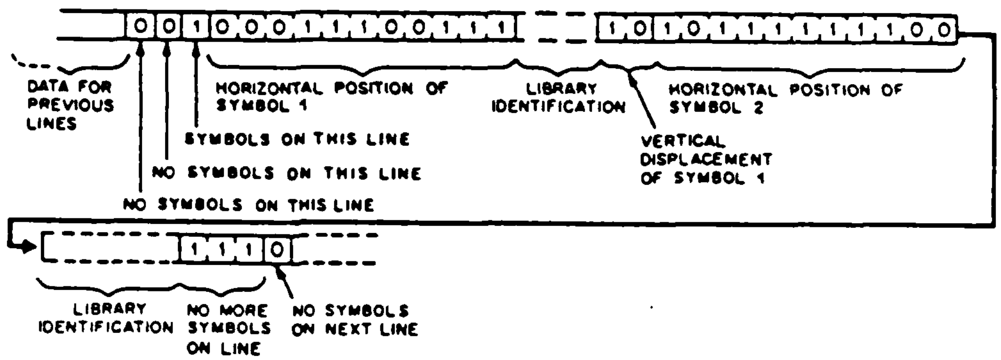


FIGURE 12 ILLUSTRATION OF THE CODING OF THE POSITIONS OF SYMBOLS IN THIS EXAMPLE, TWO LINES HAVE NO SYMBOLS, THEN A LINE HAS THREE SYMBOLS; THE FIRST ON POSITION 231 IS REPLACED BY A LIBRARY SYMBOL, THE SECOND ON POSITION 1532 IS A NEW LIBRARY SYMBOL, THERE ARE NO SYMBOLS ON NEXT LINE.

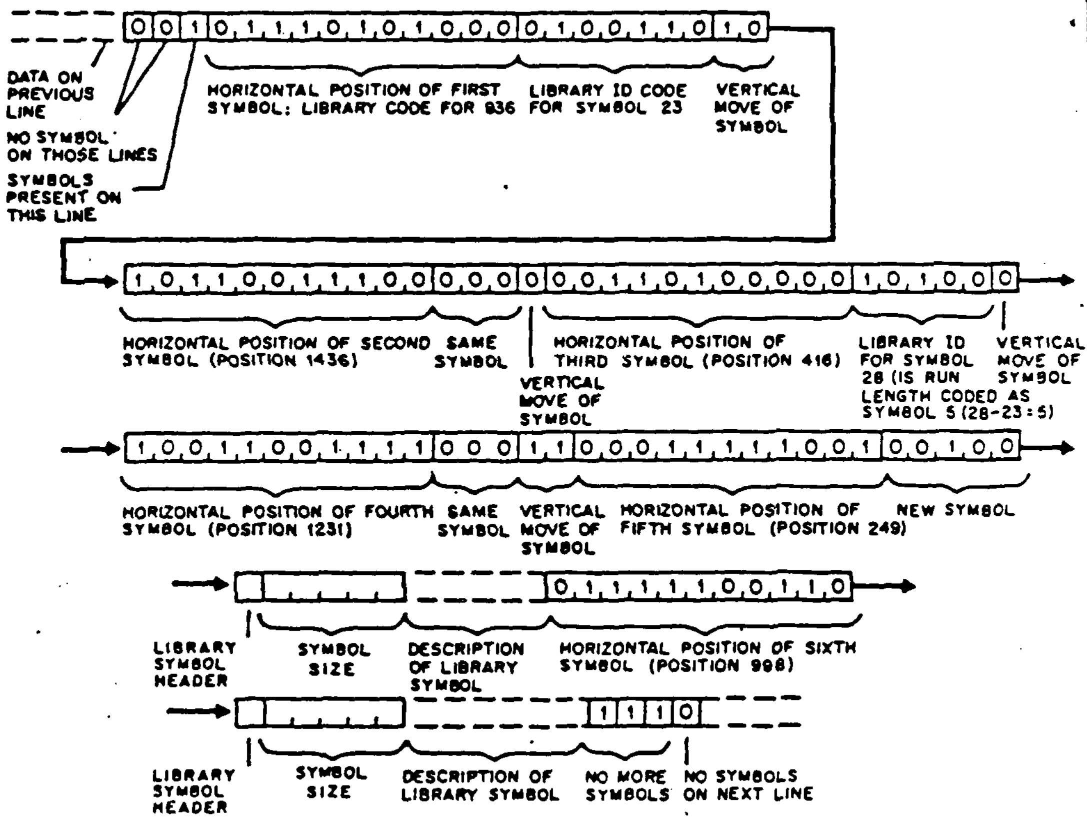


FIGURE 13 EXAMPLE OF MESSAGE TRANSMISSION. IN THIS EXAMPLE, THERE ARE TWO LINES WITHOUT SYMBOLS NEXT SYMBOL 23 IS IN POSITION 936, THE SAME SYMBOL IS IN POSITION 1436, SYMBOL 28 IS IN POSITION 416, SAME SYMBOL IN POSITION 1231; THERE ARE TWO NEW SYMBOLS ON POSITION 249 AND 998, AND THERE ARE NO SYMBOLS ON NEXT LINE.

END

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